Curriculum Booklet
M.Sc. Physics (Curriculum 2024)

Department of Physics
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Course Code	Course Name	Course Type	Semester	Credits
24MSP581T	Classical Mechanics	Theory	Semester I	3
24MSP582T	Mathematical Physics	Theory	Semester I	3
24MSP583T	Thermodynamics & Statistical Mechanics	Theory	Semester I	3
24MSP584T	Solid State Physics	Theory	Semester I	3
24MSP584P	Solid State Physics - Lab.	Practical	Semester I	1.5
21MSP505T	Numerical Methods & Computer Programming	Theory	Semester I	2
24MSP585P	Computer Programming - Lab.	Practical	Semester I	2
21MSP507T	Atomic & Molecular Physics	Theory	Semester I	3
21MSP508T	Quantum Mechanics	Theory	Semester II	4
21MSP509T	Nuclear & Particle Physics	Theory	Semester II	3
21MSP509P	Nuclear & Particle Physics - Lab.	Practical	Semester II	1.5
24MSP586T	Classical Electrodynamics & Basic Plasma Physics	Theory	Semester II	4
24MSP587T	Basic Electronics & Instrumentation	Theory	Semester II	3
24MSP587P	Basic Electronics & Instrumentation - Lab.	Practical	Semester II	6
24MSP588T	Laser Physics & Spectroscopy	Theory	Semester II	3
21RM601T	Research Methodology	Theory	Semester III	1
21MSP601	Project - I	Theory	Semester III	8
21MSP602T	Energy Harvesting & Storage Methods			3
21MSP603T	Solid State Solar & Thermal Energy Harvesting			3
21MSP604T	Wind, Hydro & Bioenergy Harvesting			3
21MSP605T	Advanced Experimental & Characterization Technique			3
21MSP606T	Advanced Experimental & Characterization Technique			3
24MSP681T	Advanced Fabrication Techniques			3
24MSP682T	Advanced Condensed Matter Physics			3
21MSP609T	Computational Techniques For Solid State Physicist			3
24MSP683T	Characterization Techniques			3
24MSP684T	Fundamentals of Ocean Sciences			3
24MSP685T	Instrumentation & Modelling of Oceans & Atmospher			3
24MSP686T	Physics & Dynamics of the Atmosphere			3
21MSP614T	Basic Communication Systems			3
21MSP615T	Organic Electronics			3
21MSP616T	Semiconductor Physics & Devices			3
24MSP687P	Advanced Electronics - Lab.			3
21MSP618P	Renewable Energy Resources - Lab.			3
24MSP688P	Advanced Fabrication & Experimental Techniques - Lab			3
24MSP689P	Atmospheric Physics & Oceanography - Lab.	Elective I, II & III	Semester III	3
24MSP690P	Advanced Condensed Matter Physics - Lab.			3
21MSP622	Project - II	Theory	Semester IV	20

Semester - 1

24MSP581T					CLASSICAL MECHANICS					
Teaching Scheme					Examination Scheme					
L	T	P	C	Hrs./Week	Theory			Practical		Total Marks
					MS	ES	IA	LW	LE/Viva	
3	0	0	3	3	25	50	25	--	--	100

COURSE OBJECTIVES

1. To master the principles of Lagrange and Hamilton, including constraints and conservation laws, to analyze dynamic systems efficiently.
2. To explore canonical transformations and their role in simplifying the description of physical systems, with a focus on central forces and oscillators.
3. To understand the dynamics of small oscillations and rigid bodies, applying concepts such as eigenvalues, Euler angles, and Noether's theorem.
4. To investigate the foundational concepts of special relativity, including inertial frames, Lorentz transformations, and their implications on classical mechanics.

UNIT I: SYSTEM OF PARTICLES **12 Hrs.**

Constraints, D'Alembert principle, Principle of virtual work, Degree of freedom, generalized coordinates and momenta, Lagrange's equation and applications, Cyclic coordinate, Symmetries and conservation laws, Hamiltonian, Lagrange's equation from Hamilton's Principle, Principle of least action derivation of equation of motion, Reduction of two body problem into single body problem, Kepler's law of motion, Scattering in centre of mass and laboratory frame of reference, Rutherford scattering.

UNIT II: CANONICAL TRANSFORMATION **10 Hrs.**

Lagrangian and Hamiltonian for central forces, coupled oscillators and other simple systems, Canonical Variables, Gauge transformation, Canonical transformation, Poisson bracket, Canonical equations in terms of Poisson bracket notation, Symmetry principles and conservations laws. The Hamilton Jacobi equations, Separation of variables, Action angle variables, Properties of action angle.

UNIT III: THEORY OF SMALL OSCILLATIONS **10 Hrs.**

Small oscillations, Eigen vectors and eigen frequencies, Orthogonality of eigen vectors, Normal coordinates, Small oscillations of particles on string, Normal coordinates. Degrees of freedom for a rigid body, Euler angles, Rotating frame, Coriolis force, Focault's pendulum, Eulerien coordinates and equations of motion for a rigid body, Noether's theorem, Motion of a symmetrical top.

UNIT IV: SPECIAL THEORY OF RELATIVITY **10 Hrs.**

Inertial Frames, Universality of Newton's second law in all inertial frames, Classical Relativity, Postulates of Special Theory of Relativity, Concept of transformation, Galilean Transformation, Poincare and Minkowski's 4-dimensional formulation, Geometrical representation of Lorentz transformations in Minkowski's space and length contraction, time dilation and causality, time-like and space-like vectors, Newton second law of motion expressed in terms of 4-vectors.

TOTAL HOURS: 42 Hrs.

COURSE OUTCOMES

On completion of the course, student will be able to:

CO1 : Apply theoretical concepts like constraints, generalized coordinates, and symmetries to derive Lagrange's equations and Hamilton's principle, solving problems related to two-body reduction and scattering in different frames.

CO2 : Use Lagrangian and Hamiltonian mechanics to analyze complex systems, including central forces and coupled oscillators, proficiently solving canonical transformations and employing Poisson brackets.

CO3 : Explore canonical transformations' mathematical formalism, incorporating Hamilton-Jacobi equations, separation of variables, and action-angle variables to simplify physical system descriptions and understand conservation laws.

CO4 : Understand small oscillations and rigid body dynamics, calculating eigenvalues and eigenvectors, applying Euler angles and Noether's theorem to analyze motion in rotating frames.

CO5 : Examine special relativity fundamentals, including inertial frames, Lorentz transformations, and their effects on classical mechanics, emphasizing geometric representation and relativistic interpretations of space-time events.

CO6 : Analyze and interpret experimental data relevant to course principles, applying theoretical concepts to practical scenarios, and drawing meaningful conclusions about dynamic systems' behavior in various physical contexts.

TEXT/REFERENCE BOOKS

1. Landau and Lifshitz, "**Mechanics**", Pergamon.
2. Goldstein, "**Classical Mechanics**", Narosa.
3. Takwale R.G. and P. S. Puranik, **"Introduction to Classical Mechanics"**, McGraw-Hill.
4. P. G. Bergmann, **"Introduction to Theory of Relativity",** Prentice-Hall.
5. R. Resnick, **"Introduction to Special Theory of Relativity"**, Wiley.

24MSP582T					MATHEMATICAL PHYSICS					
Teaching Scheme					Examination Scheme					
L	T	P	C	Hrs/Week	Theory			Practical		Total Marks
					MS	ES	IA	LW	LE/Viva	
3	0	0	3	3	25	50	25	--	--	100

COURSE OBJECTIVES

- To master Complex Variables and develop a proficiency in complex functions.
- To apply tensor operations in practical scenarios, demonstrating the ability to perform coordinate transformations
- To comprehend the relevance of groups in physics and their properties and solve problems related to symmetries.
- To gain the skills to analyze and solve integral equations for applications in physics and engineering.

UNIT 1: COMPLEX VARIABLES AND FUNCTIONS	10 Hrs.
Complex Algebra, Complex Power Series, Functions of Complex Numbers, Powers and Roots of Complex Numbers, The Exponential, Logarithmic, Trigonometric Hyperbolic, Inverse Trigonometric and Inverse Hyperbolic Functions, Analytical Functions, Contour Integral Theorem, Cauchy's Integral Formula Theorem, Laurent Series Theorem, Method of finding residues. The Residue Theorem, Evaluation of Definite Integrals by use of the residue theorem, Singularities, Mapping and Conformal Mapping.	
UNIT 2: TENSORS	**13 Hrs.**
Tensor: Introduction, n - dimensional space, superscripts and subscripts, Coordinate transformations, Indicial summation conventions, Dummy and Real indices, Kronekar delta symbol, Scalars, Contravariant vectors and covariant vectors, Tensors of higher ranks, Algebraic operations, Symmetric and Antisymmetric tensors, Invariant tensors, Conjugate and reciprocal tensors, Relative and absolute tensors, Line element and matrix tensor, Fundamental tensors.	
UNIT 3: GROUP THEORY	**13 Hrs.**
Relevance of Groups for Physics, Properties of Groups, Group Composition Table, Representations of Groups, Unitary representations, Groups with Fewer than Six Elements, Generators of Finite Groups, Symmetries of Regular Geometrical Objects, Rotations and Translations, Unitary Groups and Their Representations, Orthogonal Groups and Their Representations.	
UNIT 3: INTEGRAL EQUATIONS	**9 Hrs.**
Fredholm and Volterra Equations, Integral Transforms and Generating Functions, Neumann Series, Seperable Kernels, Numerical Solutions, Symmetrization of Kernels, Orthogonal Eigen Functions, Laplace Equations, Boundary Conditions and Uniqueness Theorems, Method of Images, Separation of Variables.	
	Max. 45 Hrs.

COURSE OUTCOMES

After completion of this course students will be able to;

CO1: To recall and identify fundamental concepts in complex algebra, tensor analysis, group theory, and integral equations.

CO2: To demonstrate an understanding of the principles of complex mathematical techniques. CO3: To apply mathematical techniques for practical problems in physics.

CO4: To analyze solutions obtained in the context of specific problems in physics.

CO5: To evaluate the validity and utility of mathematical tools and techniques assessing their applicability in diverse scenarios.

CO6: To synthesize knowledge and skills to solve real world complex physical problems.

TEXT/REFERENCE BOOK

1. Boas M.L., Mathematical methods in the physical sciences, JW, 1966
2. G. Arfken, H. Weber, & F. Harris, Mathematical Methods for Physicists
3. Mathematical Methods for Physics and Engineers, K.F Riley, M.P. Hobson and S. J.Bence, 3rd ed., 2006, Cambridge University Press
4. Palash B. Pal, A Physicist's Introduction to Algebraic Structures, Cambridge Univ. Press, 2019.
5. Mathematical Physics, S. Satyaprakash, Sultan Chand & Sons, 1990

24MSP583T					Thermodynamics and Statistical Mechanics					
Teaching Scheme					Examination Scheme					
L	T	P	C	Hrs./Week	Theory			Practical		Total Marks
					MS	ES	IA	LW	LE/Viva	
4	0	0	4	4	25	50	25	--	--	100

COURSE OBJECTIVES

1. To establish the general laws and applications of thermodynamics and introduce classical statistical mechanics.
2. To demonstrate the postulates of statistical mechanics and introduce students to quantum statistical mechanics, which is a foundational aspect of several branches of physics and has numerous applications.
3. To enable students to understand the physics of phase transitions and apply the concepts in various applications.
4. To introduce transport phenomena and non-equilibrium systems using methods from statistical physics.

UNIT I: BASICS OF THERMODYNAMICS AND CLASSICAL STATISTICAL MECHANICS **12 Hrs.**

Basics of Thermodynamics: Laws of thermodynamics and their consequences. Thermodynamic potentials, Maxwell's equation, TdS equation, Theory of heat capacity, Joule Kelvin effect, Foundations of Classical Statistical Mechanics: Microstates, Ensemble, Microcanonical Ensemble, Entropy. Maxwell Boltzmann distribution, Maxwell Boltzmann velocity distribution law.

UNIT II: QUANTUM STATISTICAL MECHANICS **12 Hrs.**

Indistinguishable particles in quantum mechanics. Bosons and Fermions. Bose-Einstein statistics, ideal Bose gas, photon gas, Bose-Einstein condensation, specific heat from lattice vibration, Debye's model of solids: phonon gas, Bose-Einstein condensation, Fermi-Dirac statistics, Fermi energy, ideal Fermi gas. Fermi gas in metals, Fermi energy as function of temperature, Applications of Fermi-Dirac statistics.

UNIT III: PHASE TRANSITIONS **10 Hrs.**

Phase transitions, Condition for phase equilibrium, First order phase transition, Clausius - Clayperon equation, The Critical exponent, Second order phase transition, Curie - Weiss theory of Magnetic transition, Ising Model, Ising Model in zeroth approximation, Exact solution of one dimensional Ising Model

UNIT IV: TRANSPORT PHENOMENON AND NON EQUILIBRIUM STATISTICAL MECHANICS **08 Hrs.**

Mean Collision time, Scattering cross section, viscosity, Electrical and thermal conductivity, Effusion and Diffusion equation, Brownian motion, Boltzman transport equation, relaxation approximation, formulation of transport theory, the conservation laws.

TOTAL HOURS: 42 Hrs.

COURSE OUTCOMES

On completion of the course, student will be able to:

CO1 : Apply thermodynamic principles, laws, and equations to analyze systems and predict behavior.
CO2 : Understand quantum statistical mechanics, including Bose-Einstein and Fermi-Dirac statistics, for describing particle behavior.
CO3 : Evaluate phase transitions, magnetism, and critical points using theoretical frameworks.
CO4 : Analyze transport phenomena and non-equilibrium systems with mathematical models.
CO5 : Synthesize knowledge from thermodynamics, statistical mechanics, and phase transitions to solve complex physical problems.
CO6 : Demonstrate critical thinking in diverse system behaviors.

TEXT/REFERENCE BOOKS

1. Mark Waldo Zemansky & Richard Dittman, **"Heat and Thermodynamics: An Intermediate Textbook"**, McGraw-Hill (1981).
2. F. Reif, **"Fundamentals of Statistical and Thermal Physics"**, McGraw-Hill Book Co. (1965).
3. P.V. Panat, **"Thermodynamics and Statistical Mechanics",** Alpha Science International Ltd (2008).
4. B. B. Laud, **"Fundamentals of Statistical Mechanics"**, New Age International Private Limited (2020).
5. Kerson Huang, **"Statistical Mechanics",** Wiley publications (2021).
6. R.K. Patharia**, "Statistical Mechanics"**, Butterworth-Heinemann publications (2001).

24MSP584T					Solid State Physics					
Teaching Scheme					Examination Scheme					
L	T	P	C	Hrs. /Week	Theory			Practical		Total Marks
					MS	ES	IA	LW	LE/Viva	
3	0	0	3	3	25	50	25	--	--	100

COURSE OBJECTIVES

1. Determine crystal structure using varied crystallographic parameters.
2. Understand energy band origins and principles behind their calculation.
3. Familiarize with diverse magnetism types and superconductivity theory.
4. Gain insights into dielectric properties and dipole organization in ferroelectrics.

UNIT 1: CRYSTAL DIFFRACTION AND RECIPROCAL LATTICE **10 Hrs.**

Introduction, Crystalline and amorphous materials – crystal systems – Bravais lattices – Miller Indices – Symmetric elements – symmetric groups – reciprocal lattice – Braggs' law, reciprocal lattice to SC, BCC, FCC, Laue's equation and Bragg's law in terms of reciprocal lattice vector, diffraction and the structure factor, structure factor of lattices (sc, bcc, fcc), atomic form factor. Imperfections in crystals.

UNIT 2: ENERGY BAND THEORY **10 Hrs.**

Classical free electron theory, density of states, Fermi-Dirac statistics, effect of temperature on Fermi distribution function, electrons in a periodic potential, Bloch's theorem, Kronig Penney Model, construction of Brillouin zone, reduced zone scheme, concept of energy band, energy band structure of conductors, semiconductors and insulators.

UNIT 3: MAGNETISM AND SUPECONDUCTIVITY **12 Hrs.**

Magnetic Susceptibility, diamagnetism, paramagnetism, the ground state of an ion and Hund's rules, nuclear magnetic resonance, electron spin resonance, Mossbauer spectroscopy, magnetic dipolar interaction, exchange interaction, ferromagnetism, antiferromagnetism, ferrimagnetism,.

Basic properties of superconductors, phenomenological thermodynamic treatment, London equation, penetration depth, superconducting transitions, Cooper pair, electron-phonon interaction, BCS theory, coherence length, flux quantization, Josephson junction, high Tc superconductors, mixed state, Applications of Superconductors.

UNIT 4: DIELECTRICS AND FERROELECTRICS **8 Hrs.**

Macroscopic Maxwell equation of electrostatics, theory of local field, theory of polarisability, dielectric constant, Claussius-Mosotti relation, dielectric breakdown, dielectric losses,

Ferroelectric, anti-ferroelectric, piezoelectric, pyroelectric, frequency dependence of dielectric properties, classification of ferroelectric crystal, ferroelectric phase transitions, relaxor ferroelectrics.

Max. <40> Hrs.

COURSE OUTCOMES

On completion of this course students will be able to;

CO1 : Establish connections between crystal structure and symmetry, and identify the relationship between real and reciprocal space.
CO2 : Apply crystallographic parameters to analyze and determine crystal structures from X-ray diffraction data.
CO3 : Evaluate electron behavior in solids using classical and quantum theories.
CO4 : Analyze magnetic phenomena and understand magnetic ordering based on material exchange interactions.
CO5 : Explain superconductivity, its properties, and key parameters for potential applications.
CO6 : Differentiate between ferroelectric, antiferroelectric, piezoelectric, and pyroelectric materials for diverse applications.

TEXT/REFERENCE BOOK

1. J.P. Srivastava, "**Elements of Solid State Physics**", PHI Learning PVT. LTD.
2. Charles Kittel, **"Introduction to Solid State Physics**", John Wiley & Sons.
3. S. O. Pillai, **"Solid State Physics**", 10^{th} Edition New age International Publishers.
4. Stephen Blundell, **"Magnetism in condensed matter"**, Oxford University Press.
5. Michael P. Marder, **"Condensed Matter Physics",** Wiley.
6. James D. Patterson, Bernard C. Bailey, **"Solid-State Physics: Introduction to the Theory"**, Springer International Publishing, 2018.

24MSP584P					Solid State Physics Laboratory					
Teaching Scheme					Examination Scheme					
L	T	P	C	Hrs/Week	Theory			Practical		Total Marks
					MS	ES	IA	LW	LE/Viva	
0	0	3	1.5	3	0	0	0	50	50	100

COURSE OBJECTIVES

1. Equip students with a comprehensive understanding of diverse experimental techniques and facilitate their proficiency in utilizing these methodologies for scientific experimentation and observation.
2. Enable students to experimentally investigate and elucidate the structural, magnetic, electrical, dielectric, and ferroelectric properties exhibited by various materials,
3. To foster deeper comprehension of material behavior through hands-on experimentation.

LIST OF EXPERIMENTS:

1. Determination of lattice constant and crystal structure of given powder sample using X-ray diffraction method.
2. To determine the dielectric constant of Various materials.
3. Investigation of Four probe and two probe resistance measurement and determination of contact resistance.
4. Investigation of B-H curve to determine the value of permeability and coercivity of various materials.
5. Study of Meissner effect, understanding of Superconductivity.
6. Studies on the Electric Spin Resonance spectrum of the given sample and determination of Landeg factor.
7. Investigation of Hall Voltage as a function of current and magnetic field and determination of Hall Coefficient and carrier concentration of the given sample of semiconductor.
8. Study of magneto resistance behavior of semiconductor/manganite materials.
9. Investigation of ferroelectric behaviour.
10. Visit of materials characterization facility of Research organization.
11. Analysis of Zinc Oxide (ZnO)/ Metal Thin Film Deposition Using Sputtering System.

COURSE OUTCOMES

On completion of this course students will be able to;

CO1 : Analyze crystal structures using crystallographic parameters and XRD data, demonstrating application and analysis skills.
CO2 : Understand magnetic, dielectric, and ferroelectric properties of materials, applying theoretical frameworks.
CO3 : Explain basic superconductivity phenomenon, demonstrating comprehension.
CO4 : Develop iterative and reflective experimental procedures, showcasing critical thinking.
CO5 : Evaluate experiment process and outcomes quantitatively and qualitatively.
CO6 : Communicate experiment process and outcomes effectively.

TEXT/REFERENCE BOOK

1. J.P. Srivastava, “**Elements of Solid State Physics”**, PHI Learning PVT. LTD.
2. Charles Kittel, **“Introduction to Solid State Physics**”, John Wiley & Sons.
3. S. O. Pillai, **“Solid State Physics**”, 10th Edition New age International Publishers.
4. Stephen Blundell, **“Magnetism in condensed matter”**, Oxford University Press.
5. Michael P. Marder, **“Condensed Matter Physics”,** Wiley.
6. James D. Patterson, Bernard C. Bailey, **“Solid-State Physics: Introduction to the Theory”**, Springer International Publishing, 2018.

21MSP505T					Numerical Methods and Computer Programming					
Teaching Scheme					Examination Scheme					
L	T	P	C	Hrs/Week	Theory			Practical		Total Marks
					MS	ES	IA	LW	LE/Viva	
2	0	0	2	2	25	50	25	–	–	100

COURSE OBJECTIVES

- To provide a basic understanding of numerical methods to solve roots of equations and linear algebraic equations.
- To introduce the basics of numerical interpolation and curve fitting.
- To provide the knowledge about to obtain solutions of mathematical operations like differentiation and integration.
- To introduce the methods to solve ordinary differential equations, boundary value problems and also providing the knowledge about Monte Carlo technique

UNIT 1: ROOTS OF EQUATIONS AND SYSTEMS OF EQUATIONS	7 Hrs.
Root Finding: Bisection method, Newton-Raphson method, Secant method, Fixed-point iteration, False position method; Linear equations: Gauss-elimination method, Gauss-Jordan method, LU decomposition, Matrix inversion by Gauss-Jordan method, Iterative methods: Gauss-Jacobin method and Gauss-Seidel method, Methods for solution of Eigen value problems.	
UNIT 2: INTERPOLATION AND LEAST SQUARES	**6 Hrs.**
Interpolation: Newton's forward and backward interpolation formulae, Lagrange's interpolation formula, Newton's divided difference formula, Inverse interpolation, Spline interpolation, Chebyshev Interpolation; Least Squares Approximation: Linear regression, Polynomial regression, Multiple linear regression, Exponential regression.	
UNIT 3: NUMERICAL DIFFERENTIATION AND INTEGRATION	**7 Hrs.**
Numerical differentiation: Forward, backward and centred difference formulae, Richardson extrapolation; Numerical integration: Midpoint rule, Trapezoidal rule, Simpson's rule, Romberg formula, Gauss-Legendre integration, Gaussian quadrature formulae (2-point, 3-point and 4-point).	
UNIT 4: ORDINARY DIFFERENTIAL EQUATIONS, BOUNDARY VALUE AND RANDOM NUMBERS	**8 Hrs.**
Numerical solution of ordinary differential equation: Initial value problems, Euler's method, Modification of Euler's method, Picard's method, Taylor Series method, Second and fourth order Runge-Kutta methods; Boundary value problems: finite difference method, Shooting Method; Stochastic methods: Random Numbers and Generators, Monte Carlo technique of numerical integration.	
	Max. <28> Hrs.

COURSE OUTCOMES

After completion of this course students will be able to;

CO1: Derive the solution of roots of polynomial equations and linear algebraic equations by using numerical methods.
CO2: Demonstrate the understanding of numerical interpolation and least squares approximations. CO3: Understand and perform numerical integration and differentiation.
CO4: Develop and implement stable numerical methods to solve ordinary differential equations
CO5: Identify and apply the appropriate numerical techniques for solving boundary value problems. CO6: Acquire the knowledge about the random numbers generators and Monte Carlo technique.

TEXT/REFERENCE BOOK

1. Numerical Methods in Engineering with Python, Jaan Kiusalaas, Cambridge University Press, 2010 (Second Edition).
2. Numerical Analysis, Timothy Sauer, Pearson, 2018 (Third Edition).
3. Numerical Methods for Engineers, Steven C. Chapra and Raymond P. Canale, McGraw-Hill Edution, 2015 (Seventh Edition).

<table>
<tr><td colspan="5">24MSP585P</td><td colspan="6">Computer Programming Lab</td></tr>
<tr><td colspan="5">Teaching Scheme</td><td colspan="6">Examination Scheme</td></tr>
<tr><td rowspan="2">L</td><td rowspan="2">T</td><td rowspan="2">P</td><td rowspan="2">C</td><td rowspan="2">Hrs/Week</td><td colspan="3">Theory</td><td colspan="2">Practical</td><td rowspan="2">Total Marks</td></tr>
<tr><td>MS</td><td>ES</td><td>IA</td><td>LW</td><td>LE/Viva</td></tr>
<tr><td>0</td><td>0</td><td>2</td><td>1</td><td>2</td><td>--</td><td>--</td><td>--</td><td>50</td><td>50</td><td>100</td></tr>
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COURSE OBJECTIVES

- To develop proficiency in Python programming.
- To enable students to implement and analyze numerical methods.
- To equip students with advanced data analysis skills.

Practical in the lab session will be related to or based on:

1.) Functionalities of Python
2.) Introduction to python modules math, cmath and matplotlib.
3.) Introduction to object oriented programming
4.) Bisection method, Newton Raphson method, Gauss Jordan method.
5.) Lagrange's and Newton's Interpolation.
6.) Gauss Seidal method for solving algebraic and transcendental equations
7.) Histograms using "boost" libraries
8.) Combining "boost" and "matplotlib" libraries for data analysis
9.) Chi2 fitting.
10.) Maximum Likelihood Fitting
11.) Hough Transformation for straight line.
12.) Image analysis for astrophysics.
13.) Spectrum Analysis, Peak Finding and Peak Resolution

COURSE OUTCOMES

On completion of the course, student will be able
CO1 – To recall and list the key functionalities of Python.
CO2 – To explain the principles of object-oriented programming in Python. CO3 – To apply numerical methods to solve mathematical problems.
CO4 – To analyze and compare the efficiency of numerical methods.
CO5 – To evaluate the accuracy of different fitting methods and assess their appropriateness. CO6 – To create comprehensive data analysis and visualization tools.

TEXT/REFERENCE BOOKS

1. Lutz, Mark. Learning Python: Powerful Object-Oriented Programming. United States: O'Reilly Media, 2013.
2. Core Python Programming, 3ed: Dr. R. Nageswara Rao, Wiley India, 2021, ISBN: 9789390457151
3. Thareja, Reema. Python Programming: Using Problem Solving Approach. Oxford University Press, 2018.
4. Guttag, John. Introduction to Computation and Programming Using Python: With Application to Understanding Data. MIT Press, 2016. ISBN: 9780262529624.

21MSP507T					Atomic & Molecular Physics					
Teaching Scheme					Examination Scheme					
L	T	P	C	Hrs./Week	Theory			Practical		Total Marks
					MS	ES	IA	LW	LE/Viva	
4	0	0	4	4	25	50	25	--	--	100

COURSE OBJECTIVES

1. To introduce students with various fundamentals of atomic physics.
2. To recognize and analyse the atomic structure and formation of atomic spectra.
3. To examine the molecular symmetry and build the solid concepts of matter and radiation interactions.
4. To apply various spectroscopic techniques to analyse and characterize molecular structure and interactions

UNIT I: ATOMIC PHYSICS **15 Hrs.**

Fine structure of hydrogen atoms, Mass correction, spin-orbit term, Intensity of fine structure lines. Effect of magnetic and electric fields: Zeeman, Paschen-Back and Stark effects. The ground state of two-electron atoms – perturbation theory and variation methods. Many-electron atoms – Central Field Approximation-LS and jj coupling schemes, Lande interval rule. The Hartree-Fock equations. The spectra of alkalis using quantum defect theory. Auger process.

UNIT II: MOLECULAR STRUCTURE **14 Hrs.**

Born-Oppenheimer approximation for diatomic molecules, rotation, vibration and electronic structure of diatomic molecules. Spectroscopic terms. Centrifugal distortion. Electronic structure-Molecular symmetry and the states. Molecular orbital and valence bond methods for $^+H_2$ and H_2. Morse potential. Basic concepts of correlation diagrams for heteronuclear molecules. Life time of atomic and molecular states. Coherence and profile of spectral lines. Rabi frequency.

UNIT III: MOLECULAR SPECTRA **14 Hrs.**

Rotational spectra of diatomic molecules-rigid and non-rigid rotors, isotope effect, Vibrational spectra of diatomic molecules-harmonic and anharmonic vibrators, Intensity of spectral lines, dissociation energy, vibration-rotation spectra, electronic spectra of diatomic molecules- vibrational structure of electronic transitions (coarse structure)-progressions and sequences. Rotational structure of electronic bands (Fine structure)-P, Q, R branches. Intensities in electronic bands-The Franck- Condon principle. The electron spin and Hund's cases. Raman Effect.

UNIT IV: SPECTROSCOPIC TECHNIQUES AND MODERN DEVELOPMENTS **13 Hrs.**

Ultraviolet and visible light spectroscopy, Fluorescence spectroscopy, Luminometry, Circular dichroism spectroscopy, Light scattering {elastic and non-elastic (Raman)}, Atomic spectroscopy: Electron Spin Resonance, Nuclear Magnetic Resonance; 3D colour X-ray spectroscopy, Terahertz Spectroscopy, Laser-Induced Breakdown Spectroscopy, Ion Mobility Spectroscopy.

TOTAL HOURS: 56 Hrs.

COURSE OUTCOMES

On completion of the course, student will be able to:

CO1 : Describe basic concepts of atomic physics and differentiate between various atomic models.
CO2 : Illustrate how coupling and interaction between the electron's spin and orbit affects atomic and molecular structure and spectra.
CO3 : Inspect various spectra and their mechanism for their wide-ranging applications.
CO4 : Relate the symmetry of molecules with the interaction between matter and radiation.
CO5 :
CO6 : Apply the knowledge of Atomic and molecular spectroscopy in solving day to day problem of life.

TEXT/REFERENCE BOOKS

1. Arthur Beiser, "**Concepts of Modern Physics"**, McGraw-Hill Book Company.
2. H. E. White, "**Introduction to Atomic Spectra"**, McGraw Hill Book Company.
3. C. N. Banwell and E. M. McCash, "**Fundamentals of Molecular Spectroscopy"**, McGraw Hill Book Company.
4. Raj Kumar, "**Atomic and Molecular Physics",** Campus Books International.
5. Gupta-Kumar-Sharma, "**Elements of Spectroscopy"**, A Pragati edition.
6. J. B. Rajam & foreword by Louis De Broglie, **Atomic physics**, S. Chand & Co.
7. G. M. Barrow, **Introduction to Molecular Physics**, McGraw Hill Book Company.
8. G. Aruldhas, **Molecular Structure and Spectroscopy**, PHI.

Semester - 2

21MSP508T					Quantum Mechanics					
Teaching Scheme					Examination Scheme					
L	T	P	C	Hrs./Week	Theory			Practical		Total Marks
					MS	ES	IA	LW	LE/Viva	
4	0	0	4	4	25	50	25	--	--	100

COURSE OBJECTIVES

1. To understand the concepts of time-independent perturbation theory and their applications to physical situations.
2. To impart knowledge about the approximation methods corresponding to time-dependent perturbation theory.
3. To enable the students to extract the structure of matter from the scattering of particles.
4. To provide an understanding of the formalism and language of relativistic quantum mechanics.

UNIT I: APPROXIMATION METHODS FOR STATIONARY STATES **16 Hrs.**

Brief introduction to identical particles and symmetry, Time-independent perturbation theory for discrete levels, non-degenerate cases and degenerate case, removal of degeneracy, Zeeman effect, Stark effect, spin-orbit coupling, fine structure of hydrogen, Variational method and its application, WKB approximation.

UNIT II: TIME DEPENDENT PERTURBATION THEORY **14 Hrs.**

Time dependent perturbation theory, Interaction picture, Transition amplitude, First- order perturbation, Harmonic perturbation, Transition probability, Second -order perturbation, Adiabatic and sudden approximation, Interaction of an atom with electromagnetic radiation Absorption and emission of radiation.

UNIT III: SCATTERING THEORY **12 Hrs.**

Non-relativistic scattering theory, scattering amplitude and cross-section, the integral equation for scattering, Born approximation, partial wave analysis, optical theorem.

UNIT IV: RELATIVISTIC QUANTUM MECHANICS **14 Hrs.**

Klein-Gordon equations, charge & current densities, physical interpretations and short comings of K-G equation, Dirac equation; Dirac matrices and their properties, spin of Dirac particle, free particle solution of Dirac equation, negative energy states and the concept of hole, electron in electromagnetic field, Spin-orbital interaction energy, Dirac equation for spherically symmetric potential.

Max Hrs: 56 Hrs.

COURSE OUTCOMES

On completion of the course, student will be able to:

CO1 : Identify the key principles and techniques of time-independent and time-dependent perturbation theory.
CO2 : Understand the differences between non-degenerate and degenerate cases in perturbation theory.
CO3 : Describe the principles of scattering theory.
CO4 : Apply time-independent perturbation theory to calculate energy corrections and wave function mixing in discrete energy levels.
CO5 : Synthesize theoretical frameworks to explain scattering phenomena in non-relativistic systems using Born approximation and optical theorem.
CO6 : Critically evaluate the physical interpretations and shortcomings of Klein-Gordon and Dirac equations in describing relativistic particles.

TEXT/REFERENCE BOOKS

1. J. J. Sakurai, "**Modern Quantum Mechanics**", Benjamin /Cummings, 1985.
2. **"Principles of quantum Mechanics"**, R. Shankar, Plenum Publishers.
3. L. Schiff, "**Quantum Mechanics**", McGraw-Hill, 1968.
4. N. Zetilli, "**Quantum Mechanics: Theory and applications**", Willey Publishers.

21MSP509P					Nuclear and Particle Physics Laboratory					
Teaching Scheme					Examination Scheme					
L	T	P	C	Hrs/Week	Theory			Practical		Total Marks
					MS	ES	IA	LW	LE/Viva	
0	0	3	1.5	3	--	--	--	50	50	100

COURSE OBJECTIVES

1. To introduce a range of experimental data and decay time acquisition and analysis techniques employed in nuclear physics.
2. To develop hands on experience of GM counter, Scintillator detectors, Multi channel analyser (MCA) and other electronics involved.
3. To learn basic precautions while handling alpha, beta and gamma sources in the laboratory.
4. To understand the interaction of radiation with matter and basic calculations of absorption coefficient, solid angle, dead time and lifetime.

LIST OF EXPERIMENTS	
1	Study of the characteristics of a GM tube and determination of its operating voltage, plateau length/slope.
2	Energy Calibration of CsI:Tl detector: Predict the energy of an unknown gamma source.
3	Depiction of Inverse square law (horizontal) using ZnS:Ag detector.
4	Dead time measurement of GM tube using alpha, beta and gamma source.
5	Energy Resolution of CsI:Tl detector and plot of variation of energy resolution with different energies and operating voltage.
6	Absolute total detection and photopeak efficiency measurements of CsI:Tl scintillator detector.
7	Linear and mass attenuation coefficient of Al absorber using GM counter and ZnS:Ag detector.
8	Determine the relative beta counting of two strong α and β sources of nuclear radiation and to determine the absorption coefficients.
9	To ascertain of the Random nature of nuclear radiation.
10	Study of Alpha particle using ZnS:Ag scintillation detector with varying operating voltage and time.
11	To measure half-life of the radioactive source.
12	Study of Alpha, beta and gamma radiation using GM detector with varying operating voltage and time.
13	To study the stochastic nature of nuclear decay by studying alpha counts of three different activity of ^{241}Am source with GM counter and ZnS:Ag detector.
14	NaI:Tl and CsI:Tl Scintillation detector-energy calibration, resolution and determination of gamma ray energy using single channel analyse and multi channel analyser (MCA).
15	Measure the decay time of the scintillator in an oscilloscope and perform two decay exponential fit for calculating the fast and slow decay time.
16	Analyze various outputs from PMT, Shaping Amplifier and SCA.
17	Study the characteriastics of a well type NaI:Tl scintillation detector.

COURSE OUTCOMES

On completion of the course, student will be able to:

CO1	:	Identify and suggest detector for measuring the basic specific property in nuclear and particle physics.
CO2	:	Determine the rate of decay of various alpha, beta and gamma sources.
CO3	:	Extend the scope of an experiments for other unknown elements other than aluminium.
CO4	:	Describe the working and detection principles of GM counter, scintillation detectors, surface barrier detector and so on.
CO5	:	Analyse the properties of radiation in nuclear physics experiments of attenuation coefficients of Aluminium and other materials.
CO6	:	Apply interaction of radiation with matter knowledge in the experiments along with basic electronics of MCA, SCA, cables and PMT.

TEXT/REFERENCE BOOKS

1. G. F. Knoll, “**Radiation Detection and Measurement”**, John Wiley and Sons, New York.
2. William R. Leo, “**Techniques for Nuclear and Particle Physics Experiments”**, Springer Berlin, Heidelberg.

21MSP509T					Nuclear and Particle Physics					
Teaching Scheme					**Examination Scheme**					
L	**T**	**P**	**C**	**Hrs./Week**	**Theory**			**Practical**		**Total Marks**
					MS	**ES**	**IA**	**LW**	**LE/Viva**	
3	**1**	**0**	**3**	**3**	**25**	**50**	**25**	**--**	**--**	**100**

COURSE OBJECTIVES

1. To develop the understanding of two nucleon system and deuteron problem.
2. To introduce properties of nuclei and details of popular nuclear models.
3. To overview the properties of nuclear decays and nuclear reactions in detail.
4. To familiarize with the fundamental forces and the dynamics of elementary particles under these forces.

UNIT I: NUCLEAR FORCES & TWO NUCLEON SYSTEM	**08 Hrs.**
Nuclear radius, Nuclear properties and their evidences, Central and tensor forces, Neutron-proton scattering, exchange character, spin dependence, charge independence and charge symmetry. Proton- proton scattering, electron scattering. Meson theory, Different types of nuclear potentials, Deuteron – Wave function and potential, Dipole and quadrupole moment, Nuclear radius and properties based on deuteron.	
UNIT II: NUCLEAR MODELS	**08 Hrs.**
Concept of Liquid drop model, Magic nuclei, nucleon separation energy, Single particle shell model (including Mean field approach, spin orbit coupling), Spin, parity, dipole and quadrupole moments from Shell model. Physical concepts of the unified model (Collective Model), Optical model.	
UNIT III: NUCLEAR DECAYS AND REACTIONS	**14 Hrs.**
Alpha decay, Electromagnetic decays: selection rules, Fermi theory of beta decay. Kurie plot. Fermi and Gamow-Teller transitions. Log (ft) value, Parity violation in beta-decay. Gamma decay, selection rules, Introduction to Nuclear Reactions (Conservation Laws, kinematics of reactions, Q-value, reaction rate, reaction cross section), Concept of Direct and compound nuclear reaction.	
UNIT IV: ELEMENTARY PARTICLES	**12 Hrs.**
Relativistic kinematics, Various Interactions, Parity, Charge Conjugation and Time Reversal, Classification: spin and parity determination of pions and strange particles. Gell-Mann Nishijima scheme. Quark model, Elementary ideas of SU(2) and SU(3) symmetry groups and hadron classification. Introduction to the standard model. Electroweak interaction-W & Z Bosons.	
	TOTAL HOURS: 42 Hrs.

COURSE OUTCOMES

On completion of the course, student will be able to:

CO1	:	Identify the basic properties of atomic nuclei, including their sizes, masses, moments, and binding energies.
CO2	:	Interpret and explain the behavior of atomic nuclei using nuclear models and analyze phenomena such as magic numbers, magnetic dipole moments, and excited states.
CO3	:	Apply the knowledge of basic laws of conservation and momentum in the determination of particle properties and processes in the subatomic world.
CO4	:	Understand the strengths and limitations of various nuclear models and theories of nuclear decay.
CO5	:	Determine and work on elementary problem solving in nuclear and particle physics, and relating theoretical predictions and measurement results.
CO6	:	Evaluate critically the results in nuclear and particle physics from fundamental forces, kinematics of elementary particles, parity violation, symmetry and transition rules by studying nuclear and weak forces.

TEXT/REFERENCE BOOKS

1. V. Devanathan. Narosa, **“Nuclear Physics”**, Narosa Publishing House, Delhi.
2. Kenneth S. Krane, “**Introductory Nuclear Physics”**, John Wiley & Sons.
3. Aaghe Bohr & Ben R. Mottelson, “**Nuclear Structure Vol. 1 & 2”** World Scientific.
4. Jean-Louis Basdevant, James Rich, Michel Spiro, “**Fundamentals in Nuclear Physics”,** Springer.
5. Thomson, Mark, “**Modern Particle Physics”,** Cambridge University Press.
6. William R. Leo, “**Techniques for Nuclear and Particle Physics Experiments”**, Springer Berlin, Heidelberg.

<table>
<tr><th colspan="5">24MSP586T</th><th colspan="6">Classical Electrodynamics and Basic Plasma Physics</th></tr>
<tr><th colspan="5">Teaching Scheme</th><th colspan="6">Examination Scheme</th></tr>
<tr><th rowspan="2">L</th><th rowspan="2">T</th><th rowspan="2">P</th><th rowspan="2">C</th><th rowspan="2">Hrs./Week</th><th colspan="3">Theory</th><th colspan="2">Practical</th><th rowspan="2">Total Marks</th></tr>
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COURSE OBJECTIVES

1. Apply Maxwell's equations to solve electromagnetic problems.
2. Analyze electromagnetic wave behaviour in various mediums.
3. Integrate classical and relativistic electromagnetism principles.
4. Develop simulations to validate electromagnetic theories computationally.

UNIT I: MAXWELL'S EQUATIONS **14 Hrs.**

Electromagnetic Induction, Faraday's Law, Induced Electric Field, Energy in Electric and Magnetic fields, Electrodynamics before Maxwell, Maxwell's correction to Ampere's Law, Maxwell's Equations, Maxwell's Equations in Matter, Continuity Equation, Poynting's Theorem, Maxwell's Stress Tensor, Conservation of Momentum and Angular Momentum, Applications.

UNIT II: ELECTROMAGNETIC WAVES **14 Hrs.**

Waves in One Dimension, Reflection, Transmission and Polarization, Electromagnetic Waves in Vaccum, The Wave Equation for E and B, Monochromatric Plane waves, Electromagnetic Waves in Matter, Propagation in Linear Media, Reflection and Transmission, Absorption and Dispersion, Wave Guides.

UNIT III: POTENTIALS, FIELDS AND RADIATION **16 Hrs.**

The Potential Formulation, Scalar and Vector Potentials, Gauge Transformations, Retarded Potentials, Jefimenko's Equations, Lienard-Wiechart Potentials, Dipole Radiation, Multipole Expansion in Radiation, Radiation Reaction, The Physical Basis of Radiation Reaction.

UNIT IV: RELATIVISTIC ELECTRODYNAMICS **12 Hrs.**

The Geometry of Relativity, The Lorentz Transformations, Relativistic Mechanics, Relativistic Energy and Momentum, Relativistic Kinematics and dynamics, Relativistic Electrodynamics, Magnetism as a Relativistic Phenomenon, The Field Tensor, Applications of Field Tensor.

TOTAL HOURS: 56 Hrs.

COURSE OUTCOMES

On completion of the course, student will be able to:

CO1 : Recall fundamental principles of electromagnetism and Maxwell's equations.
CO2 : Explain electromagnetic wave behavior in different mediums clearly.
CO3 : Apply Maxwell's equations to solve practical electromagnetism problems effectively.
CO4 : Analyze the electromagnetic phenomena using Maxwell's equations in practical terms.
CO5 : Assess the validity of electromagnetic theories in various contexts.
CO6 : Develop advanced computational models to simulate complex electromagnetic phenomena

TEXT/REFERENCE BOOKS

1. David J. Griffiths, "**Introduction to Electrodynamics"**, PHI Learning Pvt. Ltd, New Delhi
2. John David Jackson, **"Classical Electrodynamics"**, Wiley India.
3. Matthew N. O. Sadiku, "**Elements of Electromagnetics"**, Oxford University Press.
4. A. S. Mahajan and A. A. Rangwala, "**Electricity and Magnetism",** TMH Publishing.
5. B. B. Laud, "**Electromagnetics"**, New Age International.

24MSP587T					Basic Electronics and Instrumentation					
Teaching Scheme					Examination Scheme					
L	T	P	C	Hrs/Week	Theory			Practical		Total Marks
					MS	ES	IA	LW	LE/Viva	
3	0	0	3	3	25	50	25	--	--	100

COURSE OBJECTIVES

1. To introduce and analyse the operation of various electronic devices.
2. To analyse about instrumentation concepts that can be applied to control systems.
3. To study the application of electronics and create skills to set-up own designed circuits as per the requirement.

UNIT 1 OPERATIONAL AMPLIFIER AND DIGITAL IC FAMILY (MOS) **10 Hrs.**

Introduction to OPAMP, Applications: Summing, Averaging, Integrator, Differentiator. Negative and positive feedback circuits, Active filters and Oscillators, A/D and D/A converter. Digital logic circuits, Impedance matching, amplification (Op-amp based, instrumentation amp, feedback), Digital IC Families, Types of MOS, MOS Inverters, NMOS - NAND & NOR Gates. CMOS - NAND & NOR Gates, MOS parameters, Comparison of Various Logic Families. Applications: Glue logic and Analog amplifier, etc.

11 Hrs.

UNIT 2: FIELD EFFECT TRANSISTORS AND TRANSDUCERS

Introduction and Characteristic Parameters of FET, Effect of Temperature on FET parameters, FET Amplifiers, MOSFET: Depletion MOSFET, Enhancement MOSFET, Differences between JFET and MOSFET, Handling precaution for MOSFET. Opto-electronic devices (solar cells, photo-detectors, LEDs). Transducers: Temperature, Pressure/Vacuum, Magnetic fields, Vibration, Optical, and Particle detectors.

11 Hrs.

UNIT 3 TIMERS, FLIP FLOPS, SHIFT REGISTERS AND COUNTERS

Clocks & Timers: Clock waveform, TTL clock, 555 Timer (internal block diagram) as Monostable Multivibrator and as Astable Multivibrator and their application. Sequential circuits: latches and flip-flops (RS, JK, and D), comparators, Shift Registers: Types of registers, serial in - serial out, serial in - parallel out, parallel in - serial out, parallel in - parallel out, ring counter and their application. Counters: Concept of asynchronous counters (Binary counter, Decade counter), Concept of synchronous counters (4-bit up down counter) and their application e.g. Digital clock etc.

10 Hrs.

UNIT 4 DAC AND ADC, DISPLAY MULTIPLEXING

Variable register network, Binary ladder, D/A converter, D/A accuracy and resolution, A/D converter - simultaneous conversion, counter method, continuous A/D conversion, A/D techniques, Dual slope A/D conversion, A/D accuracy and resolution, application of DAC & ADC, and applications. Types of Displays: LED (seven segment), Dot matrix, LCD, Plasma and LED

Max. 42 Hrs.

COURSE OUTCOMES

On completion of the course, students will be able to

CO1: Understand the fundamental principles of operational amplifiers (OPAMPs) and their applications
CO2: Compare and contrast various types of MOS inverters and logic gates, and characteristics.
CO3: Differentiate between various types of field-effect transistors (FETs), transducers and optoelectronic devices
CO4: Design and implement sequential circuits using latches, flip-flops, shift registers and comparators.
CO5: Construct and evaluate D/A and A/D converters using variable register networks and binary ladder techniques.
CO6: Identify various digital IC families and display technologies,

TEXT/REFERENCE BOOKS

1. J.D. Ryder, "**Network, Lines and Fields**", Pearson Education India (2015)
3. J. Millman and C. Halkias, "**Integrated Electronics**", MHE (2017)
4. Leach and Malvino, "**Digital Principle and Applications**", Pearson Education India (2014)
5. J. Millman and A. Grabel, "**Microelectronics**", McGraw-Hill (1987)
6. S.M. Sze, "**Physics of Semiconductor Devices**", MHE (2021)

24MSP587P					Basic Electronics & Instrumentation Laboratory					
Teaching Scheme					**Examination Scheme**					
L	**T**	**P**	**C**	**Hrs/Week**	**Theory**			**Practical**		**Total Marks**
					MS	**ES**	**IA**	**LW**	**LE/Viva**	
0	**0**	**2**	**1**	**2**	**--**	**--**	**--**	**50**	**50**	**100**

COURSE OBJECTIVES

1. Understand foundational principles of electronic circuits.
2. Analyse behaviour of oscillator circuits.
3. Apply operational amplifier knowledge to circuit design.
4. Evaluate digital logic circuits and flip-flop operation.

LIST OF EXPERIMENTS

1. To design circuits capable of adding and subtracting voltages.
2. To construct amplifier circuits with adjustable gain and phase.
3. To utilize operational amplifiers to perform integration of input signals.
4. To demonstrate the capability of operational amplifiers in amplifying the difference between two input voltages.
5. To build an oscillator circuit capable of generating sinusoidal waveforms.
6. To create an oscillator circuit capable of producing stable oscillations using RC networks.
7. To design a circuit capable of solving linear equations using operational amplifiers.
8. To employ operational amplifiers for signal differentiation.
9. To construct a multivibrator circuit capable of generating square waveforms.
10. To explore and understand the parameters influencing the behaviour of operational amplifiers.
11. To investigate the behaviour and applications of universal logic gates.
12. To construct flip-flop circuits for digital memory and sequential logic applications.
13. To utilize the IC 555 timer to create stable and adjustable monostable and astable multivibrators.
14. To design shift register circuits capable of serial data storage and manipulation.
15. To build a counter circuit capable of counting in decimal increments.
16. To apply the concepts learned in the course to design and implement a small-scale electronic project.

COURSE OUTCOMES

On completion of the course, student will be able to:

CO1 : Recall basic principles of electronic circuits and devices.
CO2 : Comprehend working principles and applications of electronic circuits.
CO3 : Apply knowledge to design and analyse electronic circuits.
CO4 : Evaluate behaviour and performance of electronic circuits.
CO5 : Design circuit solutions for various electronic applications.
CO6 : Assess circuit performance and make informed design decisions.

TEXT/REFERENCE BOOKS

1. Micheal Sayer and A. Mansingh, **"Measurement Instrumentation and Experiment Design In Physics and Engineering"**, PHI publishers.
2. B.G. Streetman, S. Banerjee, **"Solid State Electronic Devices"** , Pearson Publications.
3. Taub and Schilling, **"Digital Integrated Electronics" ,**McGraw Hill Education.
4. Operational Amplifier **"Ramakant and Gayakwad"**, Pearson Education.
5. Donald P Leach, Albert Malvino, **"Digital Principles and Applications"**, McGraw Hill Education.

24MSP588T					Laser Physics and Spectroscopy					
Teaching Scheme					Examination Scheme					
L	T	P	C	Hrs/Week	Theory			Practical		Total Marks
					MS	ES	IA	LW	LE/Viva	
3	0	0	3	3	25	50	25	--	--	100

COURSE OBJECTIVES

- To understand the fundamental concepts of Laser principles.
- To provide the knowledge of Laser beam properties and methods of Laser pulse generation
- To provide knowledge of various Laser spectroscopic techniques
- To introduce some advanced Laser spectroscopic techniques

UNIT 1 Introduction to Lasers **10 Hrs.**

History of Laser; Interaction of radiation with matter – induced absorption, spontaneous emission, stimulated emission; Light Source; Properties of Laser, Einstein's co-efficient and Light Amplification; Population inversion – concept and discussion about different techniques; Resonant cavity.

UNIT 2 Fundamentals Concepts of Lasers **12 Hrs.**

Laser rate equations; Three & four level Lasers; Laser beam propagation; Properties of Gaussian beam; Resonator; Various types of resonators; Resonator for high gain and high energy Lasers; Gaussian beam focusing; General lasers and their types: CW and pulsed Lasers; Laser pulse generation: Q-switching and mode locking; short and ultra-short (nanosecond, picosecond and femtosecond) laser pulse generation.

UNIT 3 Introduction to Laser Spectroscopic techniques **10 Hrs.**

Laser systems for spectroscopy; Instrumentation for detection of optical signals and time-resolved measurements; Pump and probe techniques; Absorption and fluorescence spectroscopy; Raman spectroscopy: basics, instrumentation and applications.

UNIT 4 Applications of Lasers in spectroscopy **10 Hrs.**

Nonlinear spectroscopy: linear and nonlinear absorption; Terahertz spectroscopy; Special applications of laser spectroscopy: Single molecule detection, trace level detection of explosives and hazardous gases; Laser spectroscopy in material characterization; Laser-based imaging techniques, Laser-induced breakdown spectroscopy; Future of laser spectroscopy.

Max. <42> Hrs.

COURSE OUTCOMES

On completion of the course, student will be able to

CO1 - Acquire basic knowledge about the fundamental processes associated with lasers and spectroscopy CO2 - Understand and analyze the properties of the Laser beam and Laser pulse generation.

CO3 - Comprehend the significance of Lasers in spectroscopy

CO4 - Understand and learn the principles involved in various laser and spectroscopic systems CO5 - Correlate the laser properties with the spectroscopic techniques

CO6 - Develop the skills needed to solve various problems in applications related to laser and spectroscopy

TEXT/REFERENCE BOOKS

1. O Svelto, Principles of lasers, 5^{th} edition, Springer (2010).
2. W. T. Silfvast, Laser Fundamentals, 2^{nd} Edition, Cambridge University Press (2004).
3. K. Thyagrajan and Ajoy Ghatak, LASER fundamentals and its applications, 2^{nd} edition, Springer (2010).
4. Andrews and Demidov, An introduction to Laser Spectroscopy, 2^{nd} edition, Springer (2002).
5. Demtroder W, Laser Spectroscopy: Basic Concepts and Instrumentation, 3rd edition, Springer (2004)
6. Radziemski L J, Solarz R W, Paisner J A, Laser Spectroscopy and its Applications, Marcel Dekker (1987)
7. M. S. Feld and V. S. Lethokov, Nonlinear laser Spectroscopy, Springer (1980).
8. Stenholm, Foundations of laser spectroscopy, Wiley (1999).

Semester - 3

21MSP601	**Project - I**

21RM601T					Research Methodology					
Teaching Scheme					Examination Scheme					
L	T	P	C	Hrs./Week	Theory			Practical		Total Marks
					MS	ES	IA	LW	LE/Viva	
2	0	0	2	2	25	50	25	--	--	100

COURSE OBJECTIVES

1. To understand the role of research in the field of engineering and get an overview of the research process.
2. To develop proficiency in literature review techniques.
3. To understand the process of formulating and solving research problems.
4. To understand different types of intellectual property rights.

UNIT I : Introduction to Research Role of research in engineering, research process overview, types of research, outcomes of research, characteristics of a researcher, research terminology	**06 Hrs.**
UNIT II : Literature Review Techniques Searching for the existing literature, reviewing the selected literature, developing a theoretical framework, developing a conceptual framework	**06 Hrs.**
UNIT III : Formulating and Solving a Research Problem Importance of formulating a research problem, sources of research problems, identifying a problem, formulation of research objectives and research questions, Need for research design, different research designs, experimental test-setups, data sampling, data collection, data analysis & interpretation	**08 Hrs.**
UNIT VI: Intellectual Property Rights Introduction and significance of intellectual property rights, types of intellectual property rights, introduction to patents, patent drafting and filing, copyright, trademarks, industrial design, geographical indicators	**08 Hrs.**
Total	**28 Hrs.**

COURSE OUTCOMES

On completion of the course, student will be able to:

CO1 - understand the role and significance of research in engineering
CO2 - develop understanding of the basic framework of research process and design
CO3 - identify technical gaps in the literature and formulate a problem.
CO4 - develop an understanding of various research designs and techniques.
CO5 - develop an understanding of the ethical dimensions of conducting applied research
CO6 - evaluate and apply intellectual property rights concepts to the research outcomes

Reading Material

1. Stuart Melville, Wayne Goddard, Research Methodology: An Introduction for Science and Engineering Students, Juta & Co. Ltd.
2. David V. Thiel, Research Methods for Engineers, Cambridge University Press, UK
3. Ranjit Kumar, Research Methodology: A Step by Step Guide for Beginners, Pearson
4. CR Kothari, Research Methodology (Methods and Techniques), New age Publications

24MSP684T					Fundamentals of Ocean Sciences					
Teaching Scheme					Examination Scheme					
L	T	P	C	Hrs./Week	Theory			Practical		Total Marks
					MS	ES	IA	LW	LE/Viva	
3	0	0	3	3	25	50	25	--	--	100

COURSE OBJECTIVES

1. To give an overview of the science of oceanography and how it is practiced
2. To integrate all specific concepts of oceanography into a multidisciplinary analysis of the Earth
3. To stimulate students' interest and curiosity in the many and varied sciences used in the study of the oceans
4. To show importance of studying oceanography to understand future challenges.

UNIT I: EVOLUTION OF EARTH'S OCEAN **10 Hrs.**

Introduction, Evolution of earth's structure, Physiographic of ocean's origin and evolution of ocean basins (continental and oceanic basins), Continental drift, Sea floor spreading, Plate tectonics and deep sea sedimentation, Effect of changing in orbital parameters on climate change, Effect of glaciation and inter-glaciation on oceans, Last glacial maxima.

UNIT II: PHYSICAL CHARACTERISTICS **10 Hrs.**

Physical Characteristics of the Ocean: Ocean Basins, Sea floor features, Properties of sea water, Temperature, Salinity, Density and Oxygen characteristics, Vertical profile of temperature and salinity, Water mass characteristics: Formation and Classification of water mass. T-S diagram, Mixing processes in the oceans, Upwelling and downwelling processes, Oceanic heat, salt and momentum budgets.

UNIT III: GENERAL CIRCULATION **10 Hrs.**

General circulation of ocean, Thermohaline circulation, Conveyor belt formation, Abyssal circulation, mixing, ocean heat budget and transport, Wind stress, Geostrophic flow in Ocean - Ocean currents, Equatorial current systems; Wind driven ocean circulation, Ekman pumping, Ekman transports, Ocean waves, Wave spectrum, storm surges and tsunamis, Tides and tide generating forces, Atmospheric response to equatorial heating: Monsoons, Introduction to decadal phenomenon such as the PDO, Indian Ocean Dipole, Madden-Julian oscillation (MJO), Elnino and Southern Oscillation (ENSO).

UNIT IV: FUTURE OF OCEANS **12 Hrs.**

Carbon sequestration, Effect of Global warming on oceans: Sea ice formation, modifications in polar ice, ocean biogeochemistry, ocean acidification, ocean circulations, effects over cyclones, cloud formation, sea floor spreading, Future trends, Type of ocean pollution and available solutions, Major challenges in oceanography of present and future.

TOTAL HOURS: 42 Hrs.

COURSE OUTCOMES

On completion of the course, student will be able to:

CO1 : Identify atmospheric and oceanic circulation systems as well as their interconnections. CO2 : Understand basic theories explaining evolution of oceans.
CO3 : Apply the basic principles of oceanography to study generation of waves and tides. CO4 : Analyse the relationship between ocean and atmosphere.
CO5 : Evaluate effect of Global warming on the oceans.
CO6 : Develop the skills in solving various real world problems in Oceanography.

TEXT/REFERENCE BOOKS

1. Robert Stewart, **"Introduction to Physical Oceanography"**, Orange Grove Books.
2. Tomzack and Godfrey, **"Regional Oceanography"**, Pergamon.
3. J.R. Apel, **"Principles of Ocean Physics"**, Academic Press.
4. A.E. Gill, **"Atmospheric and Ocean Dynamics"**, Academic Press.
5. H.U. Sverdrup, **"The Oceans, their Physics, Chemistry and General Biology"**, Prentice-Hall Inc.
6. G. Neumann and WJ Pierson, Jr, **"Principles of Physical Oceanography"**, Prentice Hall.
7. G Dietrich, **"Descriptive Physical Oceanography"**, Academic Press.

24MSP685T					Instrumentation and modelling of Oceans and Atmosphere					
Teaching Scheme					Examination Scheme					
L	T	P	C	Hrs./Week	Theory			Practical		Total Marks
					MS	ES	IA	LW	LE/Viva	
3	0	0	3	3	25	50	25	--	--	100

COURSE OBJECTIVES

1. To introduce working principles of instrumentations employed for atmospheric studies.
2. To introduce working principles of instrumentations employed for oceanic studies.
3. To familiarize with various weather and climate models and simulation approaches.
4. To overview the basic characteristics of remote sensing imagery and its applications

UNIT I: ATMOSPHERIC MEASUREMENTS **12 Hrs.**

General principles of surface instrumental measurements, accuracy requirements, Barometer, hygrometer, anemometer, rain gauge, conventional measurements of pressure, temperature, humidity, wind, precipitation, clouds, radiosondes, Basic working principles of LIDARS, SODARS, RADAR, Doppler weather radar, Disdrometer, Aerosol measurements, Satellite meteorology: atmospheric satellite system, orbits and characteristics of different atmospheric satellite system, Applications of satellite to understand the meter, future satellite missions.

UNIT II: OCEAN INSTRUMENTATION **10 Hrs.**

Nature of Ocean instrumentation: environmental considerations, design constraints, power requirements, operational features, relevance of in-situ measurements. Sensors for salinity, DO, pH, ammonia, turbidity, wind, Solar radiation, atmospheric pressure, Portable instruments : ST meter, STD meter, CTD systems current meter, Underwater LUX meter, Shipborne Data Acquisition Systems, Marine Meteorological Data Acquisition Systems, ocean data buoys, wave rider buoys, SONAR systems, Acoustic tomography, challenges in Ocean remote sensing, recent advancements in remote sensing to understand ocean dynamics.

UNIT III: MODELING AND SIMULATIONS **10 Hrs.**

Introduction to weather and climate models - regional and global models, basic principles of modelling, shallow water models, multi-level basin scale and global ocean models, ocean wave modelling; various modelling approaches, Model Hierarchy (Simple, Intermediate, Complex); Examples of atmospheric and oceanic simulations, Governing equations in Cartesian, Isobaric and sigma coordinate systems; existing global and regional models used in weather forecasting and climate simulations.

UNIT IV: REMOTE SENSING **10 Hrs.**

Fundamentals of remote sensing, methods for detecting trace gases and particles in the atmosphere, satellite-based Sensors in Visible and Infrared Wavelengths: Low, medium and high spatial resolution sensors, tools to acquire and process remotely sensed data, satellite spectroscopy, applications of remote sensing in synoptic scale meteorology and climate change studies, space borne LIDARs, Earth Observation Satellite systems.

TOTAL HOURS: 42 Hrs.

COURSE OUTCOMES

On completion of the course, student will be able to:

CO1 : Identify various measurement techniques to measure various parameters.
CO2 : Understand basic working principles of various instrumentations used for the atmosphere and ocean studies.
CO3 : Illustrate importance of the various instruments for atmospheric and oceanic studies.
CO4 : Analyse importance of various atmosphere and ocean instrumentations.
CO5 : Evaluate applicability of different atmosphere and ocean models based on parameterization.
CO6 : Develop understanding of various methods and techniques employed for determining weather and climate changes.

TEXT/REFERENCE BOOKS

1. Wallace, J. M. and P. V. Hobbs, **Atmospheric Science - An Introductory Survey**, Academic Press.
2. Buyers, H.R., **General Meteorology**, McGraw Hill Book Company.
3. Jacobson M. Z., **Fundamental of Atmospheric Modelling**, Cambridge University Press.
4. Pedlosky J., **Geophysical Fluid Dynamics**, Springer-Verlag.
5. Holton J.R., **"An Introduction to Dynamic Meteorology"**, Academic Press.
6. Pedlosky J., **"Geophysical Fluid Dynamics"**, Springer-Verlag.

24MSP686T					Physics and Dynamics of the Atmosphere					
Teaching Scheme					Examination Scheme					
L	T	P	C	Hrs./Week	Theory			Practical		Total Marks
					MS	ES	IA	LW	LE/Viva	
3	0	0	3	3	25	50	25	--	--	100

COURSE OBJECTIVES

1. To introduce atmospheric physics, thermodynamics, turbulence in the atmospheric boundary layer
2. To familiarize with physical principles and how they determine the structures of the atmosphere and clouds
3. To discuss application relevant for studies pertaining to various disciplines of atmospheric sciences
4. To teach students the fundamental principles of atmospheric dynamics to understand various atmospheric circulations/phenomena.

UNIT I: FUNDAMENTALS OF ATMOSPHERE — 10 Hrs.

Structure of the atmosphere; Constituents of the atmosphere, Hydrostatic equilibrium, Geopotential, Hypsometric equation and scale height, Dry and wet adiabatic lapse rates, Atmospheric stability and its role pollutant transport, Atmospheric Boundary Layer, Structure and evolution, turbulence etc.

UNIT II: ATMOSPHERIC THERMODYNAMICS — 12 Hrs.

Thermodynamic laws; Thermodynamics of water vapour and moist air: Moisture parameters, Saturated adiabatic and Pseudo adiabatic processes, Conditional and convective instability, Free and forced convection; Thermodynamic diagrams; Phase change and Clausius-Clapeyron equation; Clouds: Formation and classification, rain formation processes, Atmospheric visibility: Dew, Frost and fog, smog.

UNIT III: PHYSICS OF RADIATION — 10 Hrs.

Solar and terrestrial radiation, radiation laws; absorption, emission and scattering in the atmosphere, Schwarzchild's equation; Radiation in the earth-atmosphere system: Geographical and seasonal distribution, Radiative heating and cooling of the atmosphere, Surface energy budget, The mean annual heat balance, Modification in the radiation budget with global warming. **UNIT IV: DYNAMICS OF ATMOSPHERE — 10 Hrs.**

Fundamental forces, Basic laws of conservation, hydrodynamic equations in rotating frame of reference, geostrophic and hydrostatic approximations, thermal wind, vertical motion, Circulation and vorticity; potential vorticity conservation, Boussinesq approximation; Reynolds averaging; mixing length hypothesis; Acoustic, gravity, Poincare, Rossby and Kelvin waves.

TOTAL HOURS: 42 Hrs.

COURSE OUTCOMES

On completion of the course, student will be able to:

CO1 : Identify various constituents of the earth's atmosphere along with their contribution. CO2 : Understand basic thermodynamic concepts for the atmosphere.
CO3 : Illustrate importance of thermodynamics in various atmospheric processes. CO4 : Analyse importance of radiation physics in earth's atmosphere.
CO5 : Evaluate importance of fundamentals of fluid flow to understand atmospheric circulation.
CO6 : Develop integrated knowledge of the fundamentals of atmospheric dynamics that govern weather and climate of the earth.

TEXT/REFERENCE BOOKS

1. Wallace, J. M. and P. V. Hobbs, **"Atmospheric Science - An Introductory Survey"**, Academic Press.
2. Stull, R.B., **"Meteorology for Scientists and Engineers"**, Brooks Cole.
3. Buyers, H.R., **"General Meteorology"**, McGraw Hill Book Company.
4. Jacobson M. Z., **"Fundamental of Atmospheric Modelling"**, Cambridge University Press.
5. Vallis G.K., **"Atmospheric and Oceanic Fluid Dynamics"**, Cambridge Univ. Press.
6. Pedlosky J., **"Geophysical Fluid Dynamics"**, Springer-Verlag.
7. Holton J.R., **"An Introduction to Dynamic Meteorology"**, Academic Press.
8. Pedlosky J., **"Geophysical Fluid Dynamics"**, Springer-Verlag.

24MSP689P					Atmospheric Science and Oceanography Lab					
Teaching Scheme					Examination Scheme					
L	T	P	C	Hrs/Week	Theory			Practical		Total Marks
					MS	ES	IA	LW	LE/Viva	
0	0	6	3	6	--	--	--	50	50	100

COURSE OBJECTIVES

1. To obtain practical knowledge of the instruments used in atmospheric science and oceanography .
2. To interpret and analyse remote sensing data for better understanding of short and long term weather patterns.
3. To understand ocean and atmospheric dynamics using simulations and modelling.

LIST OF EXPERIMENTS

1 To examine the air quality using concertration of CO and CO2 using digital sensor ar various spatial resolutions.
2 To do programming and data analysis of various atmospheric parameters such as temperature and humidity using Arduino UNO Mini Weather Station.
3 To analyze atmospheric data of atmospheric science with the help of MATLAB and visualization of atmospheric datasets using GRADS.
4 Examine seasonal/regional variations through the analysis of various parameters from satellite data using GRADS.
5 To investigate the difference in concentration of Particulate Matter (PM10 and PM2.5) in the selected region of interest.
6 To generate a noise pollution map within the chosen region of interest using a noise sensor.
7 To examine spatial distribution of humidity at various scales using dry and wet bulb hygrometer.
8 Vector analysis of wind speed and direction using Smart Vane Anemometer.
9 To examine the indoor and the outdoor air quality using using various parameters.
10 To interpret diurnal variation of humidity and temperature using humidy and temperature sensor.
11 Validation of digital hygrometer with wet and dry bulb hydrometer.
12 To study the wind trajectory using Hysplit model.
13 To determine amount of chloride ion, salinity and dissolved oxygen (DO) in the ocean water.
14 To examine acid-base indicators of seawater with the help of pH meter.
15 Levitus climatology of temperature and salinity – estimation of ocean mixed layer depth and climatology – T-S diagram and water mass analysis
16 Computation of latent and sensible heat fluxes using bulk formula – radiation budget – heat budget using OAFlux data – interannual variations in heat balance – heat transport
17 Study of ENSO - Southern Oscillation index – Pacific Ocean warm pool variability – Nino index – Indian Ocean Dipole Mode (IOD) to understand Interannual variability of ocean
18 To measure ozone and water vapour using Ozone monitor.
19 Calibration of a given instrument to measure proposed atmospheric parameter.
20 Lab and/or field based student mini project.

COURSE OUTCOMES

On completion of the course, student will be able to:

CO1 : Describe variation of basic atmospheric and oceanographic parameters.
CO2 : Understand the various concepts of atmospheric science, oceanography and remote sensing.
CO3 : Apply basic concepts of atmospheric science and oceanography to understand practical current problems.
CO4 : Analyze in-situ and remote sensing data to study nature and pattern of parameters.
CO5 : Examine and calculate the error in various data sets.
CO6 : Design circuits using breadboard and various components to study atmospheric and oceanographic paramenters.

TEXT/REFERENCE BOOKS

1. Stefan Emeis, **“Measurement Methods in Atmospheric Sciences: In Situ and Remote”**, Borntraeger Science Publishers.
2. Frederick K. Lutgens and Edward J. Tarbuck, **“The Atmosphere: An introduction to Meterology”**, Pearson.
3. William Emery and Adriano Camps, **“Introduction to Satellite Remote Sensing”**, Elsevier.
4. Jian Guo Liu and Philippa J. Mason, **“Image Processing and GIS for Remote Sensing: Techniques and Applications”**, Wiley Blackwell.

21MSP614T					Basic Communication Systems					
Teaching Scheme					Examination Scheme					
L	T	P	C	Hrs/Week	Theory			Practical		Total Marks
					MS	ES	IA	LW	LE/Viva	
3	0	0	3	3	25	50	25	--	--	100

COURSE OBJECTIVES

- Know amplitude modulation an demodulation techniques in detail
- Understand frequency modulation an demodulation techniques in detail
- Learn various digital communication techniques.
- Have an understanding of cellular communication and satellite communication.

UNIT 1 AMPLITUDE MODULATION/DEMODULATION TECHNIQUES **12 Hrs.**

Noise-Introduction, internal and external noises, signal to noise ratio and noise figure, Block diagram of electronic communication system. Modulation-need and types of modulation-AM, FM & PM. Amplitude modulation – representation, modulation index, expression for instantaneous voltage, power relations, frequency spectrum, Limitations of AM, Demodulation- AM detection: principles of detection, linear diode, principle of working and waveforms, Block diagram of AM transmitter and Receiver.

UNIT 2 FREQUENCY MODULATION/DEMODULATION TECHNIQUES **10 Hrs.**

Frequency Modulation: definition, modulation index, FM frequency spectrum diagram, bandwidth requirements, frequency deviation and carrier swing, FM generator-varactor diode modulator, FM detector – principle, slope detector-circuit, principle of working and waveforms. Block diagram of FM transmitter and Receiver. Comparison of AM and FM.

UNIT 3 DIGITAL COMMUNICATION **10 Hrs.**

Introduction to pulse and digital communications, digital radio, sampling theorem, types- PAM, PWM, digital modulations (FSK, PSK, and ASK). Advantage and disadvantages of digital transmission, characteristics of data transmission circuits – Shannon limit for information capacity, bandwidth requirements, data transmission speed, noise, cross talk, echo suppressors, distortion and equalizer, MODEM– modes, classification, interfacing (RS232).

UNIT 4 CELLULAR AND SATELLITE COMMUNICATION: **10 Hrs.**

Concept of cellular mobile communication – cell and cell splitting, frequency bands used in cellular communication, absolute RF channel numbers (ARFCN), frequency reuse, roaming and hand off, authentication of the SIM card of the subscribers, IMEI number, concept of data encryption, architecture (block diagram) of cellular mobile communication network, CDMA technology, CDMA overview, simplified block diagram of cellular phone handset, Comparative study of GSM and CDMA, 2G, 3G and 4G concepts.

Max. 42 Hrs.

COURSE OUTCOMES

On completion of the course, student will be able to

CO1: Explain Cellular communication and importance of frequency and amplitude modulations.

CO2: Apply the knowledge of statistical theory of communication and explain the conventional digital communication system.

CO3: Apply the knowledge of signals and system and evaluate the performance of digital communication system in the presence of noise.

CO4: Apply the knowledge of digital electronics to the real world problems.

CO5: Describe and analyze the digital communication system with spread spectrum modulation. CO6: Analyze performance of spread spectrum communication system.

TEXT/REFERENCE BOOKS

1. George Kennedy, "**Electronic Communication**", TMH (2017).
2. Roddy and Coolen, "**Electronic Communication**", PHI ((2022).
3. Kennedy & Davis, "**Electronic Communication systems**", IV edition-TATA McGraw Hill (2019).
4. Wayne Tomasi, "**Advanced Electronic Communication systems**", - Pearson education (2011)

M.Sc.					21MSP615T- Organic Electronics					
Teaching Scheme					Examination Scheme					
L	T	P	C	Hrs/Week	Theory			Practical		Total Marks
					MS	ES	IA	LW	LE/Viva	
3	0	0	3	3	25	50	0	25	0	100

COURSE OBJECTIVES

- To develop the fundamental understanding of organic semiconductors.
- To provide the comprehensive knowledge of the charge transport mechanism.
- To analyse the processing and optical-electrical characteristics of organic semiconductor devices
- Obtain the hands-on experience on organic device fabrication and characterizations

UNIT 1 Introduction to Organic Semiconductors **12 Hrs.**

Organic Semiconductors: Introduction, Organic versus Inorganic solids, Molecular materials, Electronic states in conjugated molecules, Polymer fundamentals, Conjugated polymers. Electronic transport in crystalline organic materials and conductive polymers, Charge injection at metal/organic interface.

UNIT 2 Processing of organic materials **8 Hrs.**

The essential characteristic of the electrode materials for organic electronic devices, R&D for new electrode materials, Organic electronic materials, and their processing techniques. Flexible electronics.

UNIT 3 Optoelectronic devices **12 Hrs.**

The basic structure of organic devices, OLEDs and PLEDs, Flexible displays, operating principles of organic lasers, Bulk-heterojunction, Inverted, and Tandem organic photovoltaic (OPV) devices; Carrier loss mechanisms in OPVs; Nanomorphology; Hybrid Perovskite solar cells, Dye-sensitized solar cells.

UNIT 4 other electronic devices **8 Hrs.**

Hybrid Memory devices, detector and organic thin-film transistors (OTFTs): fundamentals and working principles,

Max. 40 Hrs.

COURSE OUTCOMES

On completion of the course, student will be able to

CO1 – Explain the difference between organic and inorganic semiconductors.

CO2 – Analyze of the charge transport phenomenon in organic materials

CO3 – Design, and analysis of different layers of electronic devices.

CO4 – To explain and analysis different organic device processing

CO5 – Explain the operating principle and efficiency limitations in OPV, OLED, Laser, OTFT, Memory and Detectors

CO6 – Fabricate and characterize the hybrid devices

TEXT/REFERENCE BOOKS

1. Suganuma Katsuaki, Introduction to Printed Electronics, Springer, 2014.
2. Stergios Logothetidis, Handbook of Flexible Organic Electronics - Materials, Manufacturing, and Applications, 1st Ed., Woodhead Publishing, 2014.
3. Wolfgang Brütting and Chihaya Adachi, Physics of Organic Semiconductors, 2nd Ed., Wiley-VCH, 2012.
4. Anna Köhler and Heinz Bässler, Electronics Processes in Organic Semiconductors - An Introduction, 1st Ed., Wiley-VCH, 2015.
5. Wenping Hu, Organic Optoelectronics, 1st Ed., Wiley-VCH, 2013.
6. Sam-Shajing Sun and Larry R. Dalton, Introduction to Organic Electronic and Optoelectronic Materials and Devices, 2nd Ed., CRC Press, 2015.
7. Franky So, Organic Electronics: Materials, Processing, Devices, and Applications, CRC Press, 2010

21MSP616T					Semiconductor Physics and Devices					
Teaching Scheme					**Examination Scheme**					
L	**T**	**P**	**C**	**Hrs/Week**	**Theory**			**Practical**		**Total Marks**
					MS	**ES**	**IA**	**LW**	**LE/Viva**	
3	**0**	**0**	**3**	**3**	**25**	**100**	**25**	**--**	**--**	**100**

COURSE OBJECTIVES

➢ Develop the knowledge of applications and the necessity of electronic devices in different applications. ➢ Obtain the fundamental understanding of semiconductor physics
➢ Obtain the knowledge of electronic properties and analysis of the two-terminal and three-terminal semiconductor devices ➢ Apply the acquired knowledge to the operation mechanism of various semiconductor diodes
➢ Develop the skills in solving various real-world problems in the semiconductor device and engineering aspects.

UNIT 1 SEMICONDUCTOR PHYSICS AND PN JUNCTION **12 Hrs.**

Introduction to Semiconductor Materials, Basic Crystal Structure, Basic Crystal Growth Technique, Valence Bonds, Energy Bands, Intrinsic Carrier Concentration, Donors and Acceptors Carrier Drift, Carrier Diffusion, Generation and Recombination Processes, Continuity Equation, Thermionic Emission Process, Tunnelling Process. Basic Structure of the pn Junction, Space Charge Width and Electric Field, Junction Capacitance, Non-uniformly Doped Junctions: Linearly Graded Junction

UNIT 2 SEMICONDUCTOR HETEROJUNCTIONS AND MOSFET DEVICES **10 Hrs.**

The Schottky Barrier Diode, Metal-Semiconductor Ohmic Contacts, Heterojunctions, The Two-Terminal MOS Structure, Capacitance- Voltage Characteristics, The Basic MOSFET Operation, Nonideal Effects, MOSFET Scaling, Threshold Voltage Modifications, Additional Electrical Characteristics, Nonideal Effects, High Electron Mobility Transistor.

UNIT 3 SEMICONDUCTOR AND NANOELECTRONIC DEVICES **10 Hrs.**

Introduction to binary and ternary compound semiconductors, Tunnel Diode, IMPATT Diode, Transferred-Electron Devices, Quantum-Effect Devices, Radiative Transitions and Optical Absorption, Light-Emitting Diodes, Semiconductor Laser, Photodetector, Solar. High Electron Mobility Transistors, Quantum Interference Transistors

UNIT 4 MICROWAVE PHYSICS AND DEVICES **10 Hrs.**

Semiconductor microwave bipolar transistor, hetrojunction bipolar transistors, microwave tunnel diodes, MESFETs, CCD Devices, Gunn effect and Gunn Diode Ridley-Walkinhilsum (RHW) theory, helix travelling wave tube(TWTs), Microwave cross field Tubes(M Type), Magnetron

Max. 42 Hrs.

COURSE OUTCOMES

On completion of the course, student will be able to
CO1 – Explain the basic concepts of semiconductor physics.
CO2 – Analysis of the charge transport phenomenon in semiconducting materials and devices. CO3 – Explain and analyze the role of different interfaces
CO4 – Design the structure and analysis the bipolar transistor and MOSFET devices.
CO5 – Identify and rationalize the different two-terminal semiconductor and nano-electronic devices CO6 – Explain the operating principle and fundamentals of Microwave Physics and Devices

TEXT/REFERENCE BOOKS

1. S.M. Sze, “**Physics of Semiconductor Devices**”, John Wiley & Sons Inc., 2001
2. J. Singh, “**Semiconductor Devices - Basic Principles**”, John Wiley & Sons Inc., 2001
3. S. Sedra and K. C. Smith, “**Microelectronic Circuits**”, Oxford University Press, 2015.
4. M. S. Tyagi, “**Introduction to Semiconductor Materials and Devices**”, John Wiley & Sons Inc, 2019.
5. M. Shur, “**Introduction to Electronic Devices**”, John Wiley & Sons Inc., 2000
6. B. G. Streetman, “**Solid State Electronic Devices**”, 5^{th} Ed., PHI, 2001

21MSP605T					Advanced Experimental and Characterization Techniques-1					
Teaching Scheme					Examination Scheme					
L	T	P	C	Hrs./Week	Theory			Practical		Total Marks
					MS	ES	IA	LW	LE/Viva	
3	0	0	3	3	25	50	25	--	--	100

COURSE OBJECTIVES

1. To introduce the various advanced microscopic methods that used for the materials characterization.
2. To provide basics and working of magnetic and electric characterization techniques.
3. To introduce the principle and methods of various diffraction techniques and structure analysis.
4. To provide the basic understanding of data analysis and operation of different characterization equipment.

UNIT I: OPTICAL MICROSCOPY **09 Hrs.**

Introduction to Microscopy, Metallurgical Microscopes and Image formation, Resolution, Aberrations in Optical microscopy & its remedies, Polarized light in microscopy, Differential Interference Contrast Illumination, Hot Stage Microscopy, color metallography, and Imaging modes, Specimen preparation.

UNIT II: ELECTRON MICROSCOPY **11 Hrs.**

Brunauer-Emmett-Teller (BET) Electron-materials interactions, Scanning electron microscopy (SEM) Transmission electron microscopy (TEM), High resolution TEM (HRTEM), TEM electron energy loss spectroscopy (EELS), High-angle annular dark-field imaging (HAADF), Electron backscatter diffraction (EBSD), Selected area diffraction (SAD), Laser Confocal Microscopy. Surface profiling; Scanning probe microscopy (SPM), Scanning tunneling microscope (STM), Atomic force microscope (AFM) Working principles, working modes, Image artifacts.

UNIT III: DIFFRACTION TECHNIQUE & STRUCTURE ANALYSIS **12 Hrs.**

X-ray diffraction, Reflection High energyelectron Diffraction (RHEED), Low energyElectron Diffraction (LEED), Neutron diffraction. Structure analysis; energy dispersive X-ray analysis (EDXA), Wavelength-dispersive X-ray spectroscopy (WDXS or WDS), Extended X-ray absorption fine structure (EXAFS), Surface-extended X-ray absorption fine structure (SEXAFS), X-ray absorption near edge structure (XANES), High Power X-ray (Syncrotron). Various SAXS technique; Small-angle X-ray scattering (SAXS), Grazing-incidence small-angle X-ray scattering (GISAXS).

UNIT IV: MAGNETIC AND ELECTRIC CHARACTERIZATION TECHNIQUES **10 Hrs.**

Measuring Magnetization by Induction Method, Vibrating Sample Magnetometer (VSM), SQUID, AC susceptibility technique. Types of Measurements Using Magnetometers, Types of Measurements Using AC susceptibility, Magneto-optic Kerr effect (MOKE), Nuclear Magnetic Resonance Spectroscopy (NMR), Electron Spin Resonance Spectroscopy (ESR). Electric; Electrical resistivity in bulk and thin films, electron beam induced current measurement (EBIC), Hall effect, Magnetoresistance.

TOTAL HOURS: 42 Hrs.

COURSE OUTCOMES

On completion of the course, student will be able to:

CO1 : Demonstrate an understanding of various advanced microscopic techniques.
CO2 : Ability to recognize the appropriate microoscopic methods and apply them to various materials to obtain desired information.
CO3 : Understand of different diffraction techniques and able to analyze and determine structure of various materials
CO4 : Apply acquired knowledge to solve practical problems in magnetization measurement and electrical property analysis in various scientific and industrial contexts.
CO5 : Summarise and compare the result of different advanced methods for highly resolved microscopy.
CO6 : Analyse and interpret the data acquired from different characterization methods and came up with relevant conclusions.

TEXT/REFERENCE BOOKS

1. Y. Leng, "**Materials Characterisation: Introduction to Microscopic and Spectroscopic Methods**", Wiley.
2. Sam Zhang, L. Li & Ashok Kumar, "**Materials characterization techniques**", CRC Press.
3. D.A. Skoog, F.J. Holler, S. R. Crouch, "**Principles of Instrumental Analysis**" Cengage Learning.
4. John C. Vickerman, Ian S. Gilmore, "**Surface Analysis: The Principal Techniques",** Wiley.
5. C Suryanarayana, "**Experimental techniques in materials and mechanics**", CRC Press.

21MSP605T					Advanced experimental and characterization techniques-2					
Teaching Scheme					Examination Scheme					
L	T	P	C	Hrs./Week	Theory			Practical		Total Marks
					MS	ES	IA	LW	LE/Viva	
3	0	0	3	3	25	50	25	--	--	100

COURSE OBJECTIVES

1. To introduce the various advanced spectroscopic methods that used for the materials characterization.
2. To provide basics and working of thermal analysis and Analyze the applications of XPS and AES in various fields.
3. To introduce the principle and methods of various non-destructive testing techniques.
4. To provide the basic understanding of data analysis and operation of different characterization equipment.

UNIT I: SPECTROSCOPIC METHODS-1 **09 Hrs.**

UV visible, spectroscopy-Beer's law, Instrumentation, Quantitative analysis; Principles of vibrational spectroscopy, Vibrational spectroscopy-Raman and Infrared, Fourier transform infrared spectroscopy (FT-IR), Instrumentation, Micro Raman spectroscopy, applications, Photoluminescence spectroscopy (PL), Mossbauer spectroscopy, Applications.

UNIT II: SPECTROSCOPIC METHODS-2 **12 Hrs.**

Atomic model and electron configuration, Principles of X-ray photoelectron spectroscopy (XPS) and Auger electron spectroscopy (AES), Chemical shift, Depth profiling, Instrumentation, Applications, Scanning Auger spectroscopy (SAM), , Electron spectroscopy for chemical analysis (ESCA), X-ray fluorescence analysis (XRF), Electrochemical impedance spectroscopy (EIS); Ion beam techniques: Rutherford backscattering spectrometry (RBS), Secondary-ion mass spectrometry (SIMS).

UNIT III: NON-DESTRUCTIVE TESTING **12 Hrs.**

Elastic recoil detection analysis (ERDA), Proton induced x-ray emission (PIXE); Radiography: Introduction, Production of X-rays, working principle X-Radiography, Applications and Safety aspect, Various methods for detecting X-rays; Ultrasonic: Frequency and generation, Piezo-electric Materials for Ultrasonic Transducers, Different kind of Ultrasonic Transducers, Working of Ultrasonic Flaw Detectors, Industrial applications, Acoustic emission, Thermography, Holography, Basic principles, Applications in airframe.

UNIT IV: THERMAL ANALYSIS **09 Hrs.**

Thermo-gravimetric analysis (TGA), Differential thermal analysis (DTA), Differential scanning calorimetry (DSC), Thermomechanical analysis (TMA) and Dynamic mechanical thermal analysis (DMTA), Thermoptometry, Basic theory, Instrumentation and applications.

TOTAL HOURS: 42 Hrs.

COURSE OUTCOMES

On completion of the course, student will be able to:

CO1 : Demonstrate an understanding of various advanced spectroscopic techniques.
CO2 : Ability to recognize the appropriate spectroscopic methods and apply them to various materials to obtain desired information.
CO3 : Develop a basic background of different non-destructive testing techniques and be able to relate them to principles of physics.
CO4 : Acquire knowledge about the different thermal analysis techniques and understanding the working principle.
CO5 : Apply the fundamentals of thermodynamics extract useful qualitative and quantitative information from thermal analysis.
CO6 : Analyse and interpret the data acquired from different characterization methods and came up with relevant conclusions

TEXT/REFERENCE BOOKS

1. Y. Leng, "**Materials Characterisation: Introduction to Microscopic and Spectroscopic Methods"**, Wiley.
2. Sam Zhang, L. Li & Ashok Kumar, "**Materials characterization techniques"**, CRC Press.
3. D.A. Skoog, F.J. Holler, S. R. Crouch, "**Principles of Instrumental Analysis**" Cengage Learning.
4. John C. Vickerman, Ian S. Gilmore, "**Surface Analysis: The Principal Techniques",** Wiley.
5. C Suryanarayana, "**Experimental techniques in materials and mechanics**", CRC Press.
6. Ravi Prakash, "**Non-Destructive Testing Techniques**", New Academic Science Limited
7. Brown, "**Introduction to Thermal Analysis, Techniques & Applications**", Kluwer Academic Publishers
8. B. Raj, T. Jayakumar, M. Thavasimuthu, "**Practical Non-Destructive Testing**", Alpha Science International Limited.

24MSP688P					Advanced Fabrication and Characterization Laboratory					
Teaching Scheme					Examination Scheme					
L	T	P	C	Hrs/Week	Theory			Practical		Total Marks
					MS	ES	IA	LW	LE/Viva	
0	0	6	3	6	--	--	--	50	50	100

COURSE OBJECTIVES

1. To obtain practical knowledge of fabrication and characterization techniques.
2. To give hands-on experience of film growth technique.
3. To give hands-on experience of various characterization techniques and understand their working mechanism.

LIST OF EXPERIMENTS

1. Powder x-ray diffraction studies of given bulk material and measuring the crystallite size.
2. Determination of charge carrier mobility and concentration in a given semiconductor using Hall Effect set up.
3. Growth of thin film by RF sputtering method and analysis.
4. Growth of thin film by spin coating method and analysis.
5. UV-VIS measurement of given thin film sample.
6. Raman analysis studies of given sample.
7. Study of scanning electron microscopy (SEM) analysis of given sample.
8. Study of chemical microanalysis of given sample by energy dispersive X-ray analysis (EDXA).
9. I-V characteristic measurements of solar panel.
10. I-V characteristic measurements of memristor device.
11. I-V characteristics of fuel cell.
12. Electrical analysis of electronic device by impedance spectroscopy.

COURSE OUTCOMES

On completion of the course, student will be able to:

CO1 : Analyse the various fabrication techniques and generate designs for mini-projects.
CO2 : Evaluate the charge transport mechanism in semiconductors and interpret the data.
CO3 : Acquire the fundamental information of any semiconductor.
CO4 : Apply hands-on experience to sample preparation and data analysis using various characterization tools.
CO5 : Describe the working mechanism of various tools used in materials analysis.
CO6 : Utilize information literacy/research skills to analyse and evaluate, aiding in their systematic process of critical thought.

TEXT/REFERENCE BOOKS

1. G.S. Upadhyaya and Anish Upadhyaya, "**Materials Science and Engineering**", Viva books, New Delhi.
2. E.J. Mittemeijer, "**Fundamentals of Materials Science-the microstructure-property relationship using metals as model systems**", Springer.
3. D. Brandon and W.D. Kaplan, **"Microstructural Characterization of Materials"**, John Wiley and Sons.
4. P.W. Hawkes and J.C.H. Spence, **"Science of Microscopy"**, Springer.
5. J. Goldstein et al. **"Scanning Electron Microscopy & X-Ray Microanalysis"**, Springer.

24MSP682T					Advanced Condensed Matter Physics					
Teaching Scheme					Examination Scheme					
L	T	P	C	Hrs./Week	Theory			Practical		Total Marks
					MS	ES	IA	LW	LE/Viva	
3	0	0	3	3	25	50	25	--	--	100

COURSE OBJECTIVES

1. To introduce the basic theoretical concepts of the condensed matter physics.
2. To familiarise the students with the various aspects of the interactions effects.
3. To bridge the gap between basic solid state physics and quantum theory of solids.
4. To solve the problems related to metal-insulator transition and superconductivity.

UNIT I: THEORETICAL MODELS AND APPROXIMATIONS **12 Hrs.**

Semi-classical model of electron dynamics, Sources of electron scattering, Scattering probablity and relaxation times, Scattering at defects, scattering by phonons, Normal and Umklapp processes, Temperature dependence of electrical conductivity of metals, Mathiessesn's rules, Bloch electrons in a uniform magnetic field, cyclotron resonance, Landau levels, density of states in magnetic field, De-Haas van Alfen effect, Measurement of Fermi surface.

UNIT II: DIELECTRICS AND LATTICE VIBRATIONS **10 Hrs.**

Dielectric function of electron systems, screening, random phase approximation, plasma oscillations, optical properties of metals and insulators, excitons, polarons, fluctuation-dissipation theorem. Review of harmonic theory of lattice vibrations, anharmonic effects, electron-phonon interaction -mass renormalization, effective interaction between electrons and polarons

UNIT III: METAL INSULATOR TRANSITION **10 Hrs.**

Strongly interacting electrons in transition metal and rare earth compounds, Metal-Insulator transition, Mott insulators, Hubbard model, spin and charge density waves, electrons in a magnetic field, Landau levels, integer quantum Hall effect.

UNIT IV: SUPERFLUIDITY AND SUPERCONDUCTIVITY **10 Hrs.**

Bose-Einstein condensation and superfluidity: Landau criterion for superfluidity, Superconductivity phenomenon, BCS theory, Ginzburg-Landau theory, Review of basic postulates of superconductivity, High temperature superconductivity, Josephson junctions, SQUID magnetometer, recent advances in superconductors: MgB_2, Fe-based superconductors.

TOTAL HOURS: 42 Hrs.

COURSE OUTCOMES

On completion of the course, student will be able to:

CO1 : Analyse the sources of electron scattering during transport to comprehend their implications.
CO2 : Understand the temperature dependence of electrical conductivity in metals to interpret its fluctuations across different thermal conditions.
CO3 : Evaluate lattice vibrations and the interaction between electrons and polarons to assess their impact on material properties.
CO4 : Interpret the fundamental operating mechanism of quantum phenomena in insulators, encompassing the quantum Hall effect, to comprehend their underlying principles.
CO5 : Apply the knowledge of superconductivity towards development of high temperature superconductors.
CO6 : Employ the SQUID magnetometer to gauge exceedingly subtle magnetic fields through practical application.

TEXT/REFERENCE BOOKS

1. N. W. Ashcroft and N. D. Mermin, "**Solid State Physics**", Houghton Mifflin Harcourt, Boston, USA.
2. C. Kittel, "**Quantum Theory of Solids**", John Wiley & Sons.
3. M. P. Marder, "**Condensed Matter Physics**", John Wiley & Sons.
4. H. Ibach and H. Luth, "**Solid State Physics",** Springer Science & Business Media.
5. B.D. Cullity and C.D. Graham, "**Introduction to Magnetic Materials**", John Wiley & Sons.
6. W. Jones and N. H. March, "**Theoretical Solid State Physics**", Courier Corporation.
7. G. D. Mahan, "**Many Particle Physics**", Springer Science & Business Media.
8. J. Callaway, "**Quantum Theory of solid State",** Academic Press.
9. Nicola A. Spaldin, "**Magnetic Materials: Fundamentals and Device Applications**", Cambridge University Press.

M.Sc.					21MSP609T- Computational Techniques for Solid State Physicist					
Teaching Scheme					Examination Scheme					
L	T	P	C	Hrs/Week	Theory			Practical		Total Marks
					MS	ES	IA	LW	LE/Viva	
3	0	0	3	3	25	50	25	--	--	100

COURSE OBJECTIVES

- To acquire the basic knowledge of integral and differential equations.
- To enable the students to apply the understanding of Schrodinger equation to construct density functional theory.
- To enable the students to understand the various dynamics of molecules and apply them for practical applications.
- To provide an understanding of the formalism Monte Carlo method with various ensembles.

UNIT 1 Integral and Differential Equations	08 Hrs.
Integral equations: calculation of scattering cross section (quantum scattering with a spherically symmetric potential) , Ordinary differential equations: classical electrons in crossed electric and magnetic fields, Partial differential equations: Laplace's equation, wave equations, diffusion equation and Maxwell's equations	
UNIT 2 Schrodinger Equation and Introduction to DFT	**08 Hrs.**
Solution of the generalized eigenvalue problem, perturbation theory and solution of Schrödinger equation for electrons in atoms by Hartree-Fock, Slater approximation, Born-Oppenheimer approximation, self-consistent procedure, first principles method, introduction to density functional theory (DFT), Hohenberg-Kohn theorems, Kohn-Sham approach, exchange correlation functional: LDA and GGA, other XC functional.	
UNIT 3 Molecular Dynamics Simulation	**12 Hrs.**
Integration methods, molecular dynamics simulations, classical and tight binding molecular dynamics, Langevin dynamics simulations for Brownian motion, simulations of planetary motion, oscillatory motion, chaotic motion, quantum molecular dynamics for hydrogen molecule.	
UNIT 4 The Monte Carlo Method	**12 Hrs.**
Monte Carlo simulations with various ensembles (random number generations), estimation of energy and chemical potential, Ising model, quantum Monte Carlo, genetic algorithms, transfer matrix methods for spin chains, finite element method for partial differential equations. **Max 40 Hrs**	

COURSE OUTCOMES

On completion of the course, student will be able to

CO1 - to grasp the concepts of various techniques to solve integral and differential equations.

CO2 - to reconcile the basics of Schrodinger equation and develop various approximation schemes.

CO3 - to demonstrate an ability to understand density functional theory.

CO4 - to categorize various kind of molecular dynamics.

CO5 - to analyze various types of motion using MD simulations.

CO6 - to explain and generalize Monte carlo method for various application.

TEXT/REFERENCE BOOKS

1. J.M. Thijssen, Computational Physics, Cambridge University Press, 2007.
2. N.J. Giordano, Computational Physics, Prentice-Hall, Upper Saddle River NJ, 1997.
3. D. Frenkel and B. Smith, Understanding Molecular Simulations, Academic Press, 2002.
4. J.G. Lee, Computational Materials Science, 2nd Ed., CRC Press, Taylor and Francis Group, LLC. 2016
5. Prigogine and S.A. Rice, New Methods in Computational Quantum Mechanics, Wiley.

M.Sc.					24MSP683T- Characterization Techniques					
Teaching Scheme					Examination Scheme					
L	T	P	C	Hrs/Week	Theory			Practical		Total Marks
					MS	ES	IA	LW	LE/Viva	
3	0	0	3	3	25	50	25	--	--	100

COURSE OBJECTIVES

- To enable students to understand the importance of different characterization techniques.
- To introduce some state of the art characterization techniques.
- To provide fundamental concepts of experimental methods.

UNIT 1 Introduction to characterization techniques	**10 Hrs.**
Introduction: Importance of advanced characterization techniques for the development of materials; Scientific understanding of phenomena in materials technology; Importance of various characterization techniques: Optical, structural, morphological and spectroscopic.	
UNIT 2 Optical microscopy and diffraction methods	**12 Hrs.**
Optical microscope - Basic principles and components; Different examination modes (Bright field illumination, Oblique illumination, Dark field illumination, Phase contrast); Stereomicroscopy; Photo-microscopy; Applications. Fundamental crystallography; Generation and detection of X-rays; X-ray diffraction (XRD) techniques; XRD basics, geometry, instrumentation; Electron diffraction: Phase identification and cross sectional analysis	
UNIT 3 Electron microscopy and surface analysis	**10 Hrs.**
Interaction of electrons with solids; Scanning electron microscopy (SEM); Transmission electron microscopy (TEM): dark field, bright field imaging, high resolution mode; Specimen preparation techniques; Scanning transmission electron microscopy (STEM); Energy dispersive spectroscopy (EDS).	
UNIT 4 Advanced spectroscopic and some other techniques	**12 Hrs.**
Advanced Spectroscopic Techniques: UV-Visible Spectroscopy; Photo-luminescence spectroscopy; Infra-red spectroscopy; Raman spectroscopy; X-ray photoelectron spectroscopy (XPS). Scanning probe techniques: Principles of Scanning Tunneling Microscope (STM) and Atomic Force Microscope (AFM); Laser Confocal Microscopy; Vibration sample and Superconducting quantum interference device (SQUID) magnetometry; Thermal studies: TGA.	
	Max. <44> Hrs.

COURSE OUTCOMES

On completion of the course, student will be able to
CO1 - Acquire basic knowledge about the fundamental processes associated with various characterization techniques
CO2 - Comprehend the significance of characterization in various fields of research
CO3 - Analyze the material properties using optical microscopy and diffraction techniques
CO4 - Analyze the material properties using electron microscopy and surface analysis
CO5 - Analyze the material properties using spectroscopic and other techniques
CO6 - Apply the knowledge gained in the different areas of research

TEXT/REFERENCE BOOKS

1. Fundamentals of Nanoscale Film Analysis, Alford, Feldmen and Mayer, Springer, 2007.
2. Experimental Techniques, Sam Zhang, CRC Press, 2009.
3. Elements of X-Ray Diffraction, Cullity, and Stock, Prentice-Hall, 2001.
4. Material characterization techniques, Kumar, Li, Zhang, CRC Press, 2008.

M.Sc. Course					24MSP690P - Advanced Condensed Matter Physics Laboratory					
Teaching Scheme					Examination Scheme					
L	T	P	C	Hrs/Week	Theory			Practical		Total Marks
					MS	ES	IA	LW	Viva	
0	0	6	3	6	0	0	0	50	50	100

COURSE OBJECTIVES

- To understand and verify various underlying concepts of condensed matter physics.
- To gain practical knowledge and hands on various experimental set up in condensed matter physics.
- To acquire the skills for characterization of various samples for various properties.

List of experiments

1. Set the c-axis if the given crystal perpendicular to the incident x-ray beam.
2. Obtain the Laue photograph of the given single crystal draw gnomonic projections and index the reflections.
3. Obtain an oscillation photograph of the given single crystal about c-axis, calculate the c- dimension of the unit cell and index the reflections.
4. Determine the cell dimensions and establish the face centring of the copper and b Debye-Sherrer method.
5. Determine the value of the Hall coefficient of the given sample and determine the carrie concentration and carrier mobility.
6. Determine the relaxation time (EPR) of the given sample and the find value of g.
7. Determine the wavelength of a microwave output of a given reflex klystron oscillator and also to determine its repeller mode pattern.
8. Determine the specific heat of the given sample at room temperature and liquid nitrogen temperature.
9. Determine the Curie temperature of the given ferroelectric material.
10. Measurement of the critical temperature of the given HTc sample.
11. Study the thermo luminescence of a F centres in al alkali halide crystals.
12. Production and measurement of a low and high pressure.
13. Production and characterization of a plasma.
14. Study of Electron spins resonance.
15. Study of nuclear magnetic resonance.
16. Study of Mono and dia atomic lattice characterization.
17. Four probe measurement of magneto resistance and energy band gap of the semiconductor.
18. Verification of Wiedemann Franz law in metals,
19. Study of thermo-electric effect in various samples
20. Study of ferroelectric transition in ferroelectric materials
21. Study of Hysteresis loop in ferromagnets,
22. Determination of Susceptibility in paramagnetic fluids Quinkes method.

COURSE OUTCOMES

On completion of the course, the students will be able to

CO1 - Apply and analyse the concepts of condensed matter physics.

CO2 - Understand the practical knowhow of techniques for various structural determination.

CO3 - Demonstrate the dependence of electromagnetic properties of semiconductors on various factors.

CO4 - Investigate the effect of low and high pressure systems on various samples.

CO5 - Examine various thermoelectric effects in ferroelectric materials.

CO6 -Examine the phenomenon of superconductivity at room temperature and high critical temperature.

TEXT/REFERENCE BOOKS

1. N. W. Aschcroft and N. D. Mermin, Solid State Physics,CBS Publishing Asia Ltd., 1976
2. H. Ibach and H. Lueth, SOlid State Physics, An introduction to theory and experiment, Narosa Publishing House, 1992.
3. S. Blundell, Magnetism in Condensed Matter, 1st edition, Oxford University Press, 200.1
4. J. Singleton, Band Theory and electronic properties of solids, 1st edition Oxford University Press, 2001.

21MSP602T					ENERGY HARVESTING AND STORAGE METHODS					
Teaching Scheme					Examination Scheme					
L	T	P	C	Hrs./Week	Theory			Practical		Total Marks
					MS	ES	IA	LW	LE/Viva	
4	0	0	4	4	25	50	25	--	--	100

COURSE OBJECTIVES

1. TO INTRODUCE PRINCIPLES OF ENERGY CONVERSION TO USEFUL FORM OF ENERGY FOR HARVESTING ENERGY.
2. TO REALIZE ROLE OF THE THERMAL ENERGY STORAGE CONVERSION DEVICES, LIMITATIONS AND APPLICATIONS.
3. TO APPRECIATE SMART MATERIALS AS ELECTROCHEMICAL ENERGY STORAGE BATTERIES AND ORGANIC LI-BATTERIES
4. TO KNOW THE SIGNIFICANCE OF HYDROGEN IN STORAGE MECHANISM AND ITS PIVOTAL ROLE IN FUEL CELL TECHNOLOGY

UNIT I: ENERGY CONVERSION AND HARVESTING **10 Hrs.**

Basics of energy: Different forms of energy, energy conversion process, indirect and direct, Basics of Daylighting, Energy storage: Energy demand, energy storage methods; Energy and environment correlations: Environmental Impact Assessment and Life cycle analysis (LCA); Energy conservation: Audits, Planning and implementation.

UNIT II: THERMAL ENERGY STORAGE (TES) **12 Hrs.**

Concepts of internal energy, entropy, enthalpy; Gas laws, Thermodynamic cycles, Irreversible and Reversible processes, Carnot cycle, Carnot engine, Psychometrics and use of psychrometric chart; Thermal energy and storage, Solar energy and TES, TES methods, Sensible TES, Latent TES, Cold TES, Seasonal TES; Environmental Impact: TES systems and Applications.

UNIT III: ELECTROCHEMICAL ENERGY & STORAGE **10 Hrs.**

Concept of electrochemical energy, Batteries and supercapacitors: recent development; Advanced Li-ion: Positive and negative electrode materials for Li-ion technology; Capacitive Storage: Carbonatedand Pseudo-capacitive materials, Electrolytes for supercapacitors.

UNIT IV: HYDROGEN ENERGY **10 Hrs.**

Hydrogen production (Electrolysis method, Thermo-chemical methods, Fossil fuel methods, solar energy methods), Hydrogen storage, Hydrogen transportation, Utilization of Hydrogen Gas, Safety and management, Hydrogen technology development. Design and principle of operation of a Fuel Cell (H_2, O_2 cell), Conversion efficiency of Fuel Cells, Applications of Fuel Cells.

TOTAL HOURS: 42 Hrs.

COURSE OUTCOMES

On completion of the course, student will be able to:

CO1 : Gaining Proficiency In The Comprehension Of Methods Of Harvesting And Storing Renewable Energy.
CO2 : Attain Fundamental Knowledge In The Comprehension Of Thermal Energy And Different Storage Methods.
CO3 : Compare The Efficiency And Energy Production From Thermal, Electrochemical And Solar Energy Harvesting And Storage Methods.
CO4 : Explain Operating Mechanism Of Harvesting Energy From Thermal, Electrochemical And Solar Storage Methods.
CO5 : Achieving A Comprehensive Grasp Of Li-Ion Battery And Supercapacitors Technology.
CO6 : Analyse The Past, Current And Future State Of Development In Hydrogen Generation, Storage And Application In Fuel Cells.

TEXT/REFERENCE BOOKS

1. J.A. DUFFIE & W. A BECKMAN, "**SOLAR ENGINEERING OF THERMAL PROCESS**", JOHN WILEY &SONS.
2. S.P. SUKHATME, "**SOLAR ENERGY PRINCIPLES OF THERMAL COLLECTION AND STORAGE"**, TMH.
3. I. DINCER AND M. A. ROSEN, "**THERMAL ENERGY STORAGE: SYSTEMS AND APPLICATIONS"**, WILEY.
4. H. P. GARG AND J PRAKASHI, "**SOLAR ENERGY",** TMH.
5. J. M. TARASCON AND P. SIMON, "**ELECTROCHEMICAL ENERGY STORAGE"**, WILEY.

M.Sc. Course					21MSP603T- Solid State Solar and Thermal Energy Harvesting					
Teaching Scheme					Examination Scheme					
L	T	P	C	Hrs/Week	Theory			Practical		Total Marks
					MS	ES	IA	LW	LE/Viva	
3	0	0	3	3	25	50	25	--	--	100

COURSE OBJECTIVES

- To introduce fundamental and recent advances of energy harvesting from two of the most abundant sources, namely solar and thermal energies.
- To understand characteristics and design of common types of solar cells.
- To apply known approaches to increasing solar cell efficiency.
- To familiarize basic physical properties, Seebeck coefficient, electrical and thermal conductivities, and analysis through the Boltzmann transport formalism.

UNIT 1 FUNDAMENTALS OF PHOTOVOLTAICS	12 Hrs.
Solar resource, properties of sunlight, Light Absorption, Optical Losses, energy bands, doping, electric field, potential, Charge generation and Recombination, Basic Equations of Device Physics, drift current, diffusion current, P-N junction, Charge separation, 1-D device model, Commercial silicon solar cell technology, Current-voltage and quantum efficiency measurements and energy conversion efficiency analysis	
UNIT 2 ADVANCE PV CONCEPTS AND RELIABILITY	**12 Hrs.**
Commercial thin film photovoltaic technologies, Various solar cells introduction: including multijunction, multiple excitation generation, multibarrier, quantum dot, hot carrier, intermediate band, plasmonic, heterogenous, dye sensitized, and perovskite solar cells, Materials Properties Affecting Performance, Approaches to increasing solar cell efficiency. Modules, Systems, and Reliability.	
UNIT 3 THERMOELECTRICITY	**11 Hrs.**
Thermoelectric effect: Peltier effect, Seebeck effect, and Thomson effect, Physical properties of thermoelectric materials, Seebeck coefficient, electrical and thermal conductivities, the Boltzmann transport formalism, Carrier scattering time approximations in relation to dimensionality and the density of states, energy filtering, quantum confinement, size effects, band structure engineering, and phonon confinement, Thermoelectric generator (TEG) or Seebeck generator.	
UNIT 4 SOLAR PV POWER PLANTS	**10 Hrs.**
Energy yield forecast, irradiance on module plane, performance modeling, uncertainty in energy yield prediction, Plant Design: Technology selection, layouts, electrical design, sizing of invertors, cables, fuses and protection devices, optimizing system design and its construction Commissioning of plant: General recommendation, pre-connection acceptance testing, grid connection; Operation and maintenance of the power Plant.	
	Max. 45 Hrs.

COURSE OUTCOMES

On completion of the course, student will be able to

CO1 – Explain the operation of various solar cells including multijunction, multiple excitation generation, multibarrier, quantum dot, hot carrier, intermediate band, plasmonic, heterogenous, dye sensitized, and perovskite solar cells.

CO2 – Outline the parameters affecting the behaviour of various solar cells and thermoelectrics.

CO3 – Distinguish the underlying physics of electron and phonon transport in semiconductors.

CO4 – Identify the promising density of states, lattice structure, and phonon dispersion for efficient solar cell and thermoelectric energy conversion.

CO5 – Explain the microscopic origin of Peltier effect, Seebeck voltage, and Thomson effect.

CO6 – Evaluate the effectiveness of strategies for selecting solar PV technology.

TEXT/REFERENCE BOOKS

1. Semiconductor Devices, Physics and Technology, M. Sze and M. K. Lee, Wiley, 3rd edition, 2012.
2. The physics of solar cells, Jenny Nelson, Imperial College Press, 2003.
3. Solar Energy From Cells To Grid, Brijesh Tripathi , Manoj Kumar, CSMFL Publications, 2018.
4. Introduction to Thermoelectricity, Julian Goldsmid, 2nd Edition, Springer-Verlag Berlin Heidelberg, 2016.
5. Materials, Preparation, and Characterization in Thermoelectrics, David Michael Rowe, CRC Press, 1st edition, 2016.

M.Sc. Course					21MSP604T- Wind, Hydro and Bioenergy Harvesting					
Teaching Scheme					Examination Scheme					
L	T	P	C	Hrs/Week	Theory			Practical		Total Marks
					MS	ES	IA	LW	LE/Viva	
3	0	0	3	3	25	50	25	--	--	100

COURSE OBJECTIVES

- To introduce principles of conversion to useful form of energy from wind, hydro and bioenergy resources.
- To emphasis the wind, hydro and bioenergy resource assessment and site selection techniques.
- To appreciate the power of osmotic energy harvesting along with wind, hydro and bioenergy.
- To realize role of the conversion devices, limitations, cost of energy generation and environmental issues during energy harvesting.

UNIT 1 WIND ENERGY HARVESTING	11 Hrs.
Introduction: Factors influencing wind, Wind resource assessment, Weibull distribution; Betz limit, Wind energy conversion systems: classification, applications, power, torque and speed characteristics; General theories of wind machines, Basic laws and concepts of aerodynamics, Description and performance of the horizontal–axis wind machines, Blade design, The generation of electricity by wind machines, case studies.	
UNIT 2 HYDRO ENERGY HARVESTING	**11 Hrs.**
Hydrology, Resource assessment, Potential of hydropower in India, Classification of Hydropower Plants, Overview of micro mini and small hydro, Site selection and civil works, Penstocks and turbines, Speed and voltage regulation, Investment issues, load management and tariff collection, Distribution and marketing issues, case studies, Wind and hydro based stand-alone / hybrid power systems.	
UNIT 3 OSMOTIC POWER HARVESTING	**11 Hrs.**
Introduction: Diffusion, Principle of Osmosis, Types of osmotic power generation: Pressure retarded osmosis (PRO) and Reversed electro dialysis (RED) fresh and saline water availability, Salinity and Temperature gradient, Osmotic power generation: Pre-treatment, membrane stacks, pumps, pipes and turbines; Areas of application and Potential locations for an osmotic power plant, Capacity of an Osmotic power plant: Net energy production, Main infrastructure.	
UNIT 4 BIOENERGY HARVESTING	**12 Hrs.**
Introduction to bioenergy; biomass harvesting; availability and assessment of biomass for bioenergy applications; characterization and classification of biomass feedstock (physico-chemical properties, ultimate, proximate, compositional, calorific value, thermogravimetric, differential thermal and ash fusion temperature analyses); classification of biomass feedstock: first, second and third generation biofuels; hybrid biofuels, Different pre-treatment processes of biomass; different production routes for biomass conversion to biofuels.	
	Max. 45 Hrs.

COURSE OUTCOMES

On completion of the course, student will be able to

CO1 – Identify various microphysical concepts such as fluid dynamics, thermodynamic, classical mechanics involved in the power generation mechanism.

CO2 - Determine the various impacts of wind, hydro, osmotic and bioenergy harvesting on the environment and sustainable development.

CO3 – Compare the efficiency and energy production from wind, hydro, osmotic pressure and bio energy resources.

CO4 – Explain the design and analyse the basic operating mechanism of harvesting energy from wind, hydro, osmotic pressure and bio energy resources.

CO5 – Apply the knowledge of site selection and case studies for proposing power plant based on wind, hydro, osmotic or bioenergy resources.

CO6 – Analyze the past, current and future state of development in wind, hydro, osmotic pressure and bio energy harvesting.

TEXT/REFERENCE BOOKS

1. Wind Energy: Renewable Energy, V. Nelson, CRC Press, 2009.
2. Manwell J. F., McGowan J. G. and Rogers A. L., Wind Energy Explained – Theory, Design and Application John Wiley & Sons, Ltd., 2002.
3. Biomass to Renewable Energy Processes, J. C. Jay, Taylor and Francis, CRC Press, 2018.
4. Understanding Clean Energy and Fuels from Biomass, H. S. Mukunda, Wiley India, 2011.
5. Renewable Energy Resources, Twidell, John, and Tony Weir, Taylor and Francis, 2005.
6. Bio-inspired Nanocomposite Membranes for Osmotic Energy Harvesting, Cheng Chen, et al., Joule 4, 247–261, January 15, 2020.
7. Blue Energy and Its Potential: The Membrane Based Energy Harvesting, Shubham Lanjewar, et al., Advances in Membrane Technologies, 2020.
8. Micro-Hydro Design Manual: A Guide to Small-Scale Water Power Schemes, Harvey A., Brown A. and Hettiarachi P., ITDG, 1993.
9. Renewable Energy Source and Conversion Technology, N.K Bansal, M. Kleemanm & M. Melss, TMH.

21MSP618P					Renewable energy resource laboratory					
Teaching Scheme					**Examination Scheme**					
L	**T**	**P**	**C**	**Hrs/Week**	**Theory**			**Practical**		**Total Marks**
					MS	**ES**	**IA**	**LW**	**LE/Viva**	
0	**0**	**2**	**1**	**2**	**--**	**--**	**--**	**50**	**50**	**100**

COURSE OBJECTIVES

1. Gain a comprehensive understanding of various renewable energy systems by conducting scientific experiments and observations.
2. Acquire practical knowledge in renewable energy resources through hands-on experimentation.
3. Develop a foundational understanding of renewable energy generation and utilization concepts.
4. Apply renewable energy principles to design systems suitable for both home and commercial applications.

LIST OF EXPERIMENTS

1 Solar radiation measurements for solar energy experiments including I-V measurements of solar panel.
2 To study areal characteristics of solar panel with tilt angle.
3 To study the operation of photo-voltaic panes in series/parallel using variable light source.
4 To determine the temperature change of water in a solar collector.
5 To study thermal storage of energy in a tank of water.
6 To study the effect of concentrating sunlight of the output from a solar cell.
7 Wind turbine experiment to determine the specific wind power and wind frequency.
8 To study effect of fan speed on the power output of a wind turbine.
9 Thermoelectricity experiment to study the Seebeck effect and the Peltier effect.
10 Fuel cell experiment to study about working of a hydrogen fuel cell a power source.
11 To analyse cyclic voltammogram of a capacitor/supercapacitor for electrical energy storage analysis.
12 Mini project with creative ideas in line with Renewable Energy Resources.

COURSE OUTCOMES

On completion of the course, student will be able to:

CO1 : Apply experimental techniques to analyze solar energy systems, including solar radiation measurements and I-V measurements of solar panels
CO2 : Investigate the performance factors affecting solar panels, such as tilt angle and concentration of sunlight
CO3 : Demonstrate the operation and configurations of photovoltaic panels, including series and parallel connections, under variable light conditions
CO4 : Analyze the thermal characteristics of renewable energy systems, including the temperature change of water in solar collectors and thermal storage in water tanks
CO5 : Evaluate the performance of wind turbines by studying specific wind power, wind frequency, and the effect of fan speed on power output
CO6 : Design and implement innovative renewable energy projects, showcasing creativity and problem-solving skills

TEXT/REFERENCE BOOKS

1. V. Nelson, “Wind Energy: Renewable Energy”, CRC Press, 2009.
2. Manwell J. F., McGowan J. G. and Rogers A. L., Wind, “Energy Explained – Theory, Design and Application” John Wiley & Sons, Ltd., 2002.
3. J. C. Jay, “Biomass to Renewable Energy Processes”, Taylor and Francis, CRC Press, 2018.
4. S.P. Sukhatme,”Solar Energy Principles of Thermal Collection and Storage”, McGraw-Hill Education (India)

Semester – 4

21MSP622	**Project - II**